

UNCLASSIFIED

AD NUMBER	
AD108456	
CLASSIFICATION CHANGES	
TO:	UNCLASSIFIED
FROM:	CONFIDENTIAL
LIMITATION CHANGES	
TO: Approved for public release; distribution is unlimited.	
FROM: Controlling DoD Organization: Chemical Corps Board, Army Chemical Center, MD.	
AUTHORITY	
ECBC memo dtd 18 Feb 2016; ECBC memo dtd 18 Feb 2016	

THIS PAGE IS UNCLASSIFIED

UNCLASSIFIED

AD NUMBER

AD108456

CLASSIFICATION CHANGES

TO:

CONFIDENTIAL

FROM:

SECRET

AUTHORITY

31 Dec 1968, Group 3, DoDD 5200.10

THIS PAGE IS UNCLASSIFIED

AD- 108456

SECURITY REMARKING REQUIREMENTS

DOD 5200.1-R, DEC 78

REVIEW ON 28 DEC 76

CONFIDENTIAL

AD

108456

REVIEW ON:

1 Dec 90.

EXTENDED BY:

CG USA Armament
R&D Comd

REASON:

AUTHORITY:

Army Armament Research
And Development Command
Letter dated 21 Dec 80.

Defense Technical Information Center

Defense Logistics Agency

Cameron Station

Alexandria, Virginia 22314

CONFIDENTIAL

*Reproduced
by the*

ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA



DOWNGRADED AT 12 YEAR
INTERVALS: NOT AUTOMATICALLY
DECLASSIFIED. DOD DIR 5200.10

CONFIDENTIAL

AI 08456

Armed Services Technical Information Agency

Reproduced by
DOCUMENT SERVICE CENTER
KNOTT BUILDING, DAYTON, 2, OHIO

This document is the property of the United States Government. It is furnished for the duration of the contract and shall be returned when no longer required, or upon recall by ASTIA to the following address: Armed Services Technical Information Agency, Document Service Center, Knott Building, Dayton 2, Ohio.

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

CONFIDENTIAL

SECRET

FC

REPORT ON

PROPERTIES OF WAR GASES (U)

Volume I

G AGENTS (U)



Chemical Corps Board
Army Chemical Center, Maryland

Copy 77 of 250 Copies
Volume I of IV Volumes

SECRET

CCB- 17 000 -3 (U)

7

**NOTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE
NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING
OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794.
THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN
ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.**

2

SECRET

*** "REPORT ON PROPERTIES OF WAR GASES"**

Volume I

G Agents

* "Report on Properties of War Gases" is published in four volumes:

- Volume I - G Agents
- Volume II - Blood and Nettle Gases
- Volume III - Vomiting & Choking Gases and Lacrimators
- Volume IV - Vesicants

"Bibliography" and "Glossary of Symbols" are included as appendices to Volume IV.

Chemical Corps Board
Army Chemical Center, Maryland

SECRET

56

30881

UNCLASSIFIED

LIST OF CONTENTS

Foreword

Introduction

Agents - GA
GB
GD
GF

UNCLASSIFIED

UNCLASSIFIED

FOREWORD

There exists at the present time in the Chemical Corps' technical literature a great deal of uncertainty concerning the properties of the most important war gases. This uncertainty has resulted from the fact that most of the data that are now available have never been collected into one volume and properly collated and evaluated. Since such properties of war gases play an important role in many aspects of chemical warfare research, the need for a standard handbook on these properties exists.

In an attempt to fulfill such a need, it was proposed to revise the Chemical Corps Board Study 35-48, "Properties of War Gases," dated 21 March 1950, with the object of gathering the most reliable information available on the subject. Intentions were to make the study as comprehensive and complete as possible. In order to accomplish this task, a method of exhaustive literature research had been employed. This research was begun in October 1952 and was continued through November 1954, compiling protection data and data on the physical and chemical properties of the agents included in this study.

The toxicology data for this study were supplied by CmlC Medical Laboratories. This information was requested by the Chemical Corps Board in a letter to CmlC Research and Engineering Command; Letter, CMLEK-AMW, Chemical Corps Board, 21 June 1954, subject: "Revision of Chemical Corps Board Study 35-48."

This study does not include the data on the physical and chemical properties (categories 1 through 14) for the mustard agents. The data are being assembled by CmlC Chemical and Radiological Laboratories. Informal coordination with Dr. Wardell, Information Group, indicates that their report on the properties of HD, Q, and T will be completed in the near future; however, the data on HQ, HT, HL, L, HN1, and HN3 will require more time.

CmlC Research and Engineering Command have agreed to assume the responsibility of keeping the study on an up-to-date status.

UNCLASSIFIED

UNCLASSIFIED

NOTE

All classified documents cited in this report appear under the call numbers given them by the Technical Library of Army Chemical Center, Maryland.

UNCLASSIFIED

1

UNCLASSIFIED

INTRODUCTION

A. The material for each agent has been divided into 25 categories. These categories are as follows:

1. Bibliography of Second Sources of Information on the Agent
2. Name, Formula, Molecular Weight
3. Physiological Action, Tactical Use, Status, Russian Interest
4. Physical State, Melting Point, Boiling Point
5. Liquid Density
6. Solubility in Organic Solvents
7. Solubility in Water
8. Hydrolysis
9. Effect of Heat and Blast
10. Stability in Storage, Action on Metals
11. Latent Heat of Vaporization
12. Relative Vapor Density
13. Vapor Pressure
14. Volatility in Atmospheric Air
15. Odor and Median Detectable Concentration
16. Toxicity by Inhalation
17. Eye Toxicity
18. Oral Toxicity
19. Skin Toxicity and Clothing Penetration
20. Speed of Action
21. Detoxication in the Body

UNCLASSIFIED

UNCLASSIFIED

22. Medical Protective or First Aid Measures

23. Detection

24. Individual Protection

25. Decontamination

- B. The remainder of the introduction consists, in effect, of 25 individual introductions to the 25 categories outlined in paragraph A, above. Readers finding themselves unfamiliar with some aspect of the information given in any category in the body of the report should refer to the corresponding category in the introduction for an explanation.**

UNCLASSIFIED

UNCLASSIFIED

Intro - 1

CATEGORY 1

**BIBLIOGRAPHY OF SECONDARY SOURCES
OF INFORMATION ON THE AGENT**

Category 1 of each agent consists of a list of reports which were found, during the course of literature research, to be secondary sources of information dealing exclusively with the agent (or the agent and a group of related compounds) and containing no original information. Many of these reports are very comprehensive summaries of the work that was done over certain periods of years on the agent. They are given in category 1 for the convenience of the reader who may desire information beyond the scope of this document.

UNCLASSIFIED

UNCLASSIFIED

Intro - 2

CATEGORY 2

NAME, FORMULA, MOLECULAR WEIGHT

1. All agents have been named according to the system of chemical nomenclature that was adopted by the American Chemical Society in 1953.
2. Both the empirical and structural formulas of each agent are given. The order in which the elements are given in the empirical formula conforms to the system used in the formula indexes of Chemical Abstracts.
3. All molecular weights have been calculated to two decimal places using the set of international atomic weights published by the American Chemical Society in 1953.

UNCLASSIFIED

UNCLASSIFIED

Intro - 3

CATEGORY 3

PHYSIOLOGICAL ACTION, TACTICAL USE, STATUS,
RUSSIAN INTEREST

The information given in this category for each agent is by no means complete. Category 3 has been included in this document merely to give a reader who is unfamiliar with war gases an idea of how each agent acts upon the body, how it may be used in chemical warfare, and how much American and foreign interest there is in the agent at the present time. Each of these topics is treated in as few words as possible.

UNCLASSIFIED

UNCLASSIFIED

Intro - 4

CATEGORY 4

PHYSICAL STATE, MELTING POINT, BOILING POINT

1. By melting point (MP) or freezing point (FP) in this document is meant that temperature at which an infinitesimal amount of the solid phase of an agent is in equilibrium with the agent's liquid phase. Theoretically, the MP and FP of an agent are the same temperature. In practice, however, the two may differ somewhat depending upon the method employed. The use of the symbols "MP" or "FP" is arbitrary. "MP" is generally used if the temperature is approached from below (by heating) and "FP" if the temperature is approached from above (by cooling). The symbol used for each value that is given in this document is the same as the symbol used by the investigator who reported the value.
2. The triple point (TP) of a compound is defined as the temperature at which all three phases of the compound (solid, liquid, and vapor) are in equilibrium. It is the compound's MP (or FP) under its own vapor pressure. The MP discussed in paragraph 1 (above) differs from the TP in that it is usually determined under atmospheric pressure. For most compounds this difference is negligible, however, and, except in very precise work, the two temperatures may be considered the same. The vapor pressure that is given for each agent at its TP therefore has been calculated using the agent's selected MP.
3. By boiling point (BP) in the title of this category is meant the agent's normal boiling point, that is the temperature at which the agent exhibits 760 mm Hg pressure. Boiling points reported at reduced pressures are given in category 13.
4. In calculating the BP's of those agents that are mixtures, experimental vapor pressure data have been used whenever such data were available. In any case where experimental data were not available, the agent was assumed to obey Raoult's law and the BP was calculated accordingly.

UNCLASSIFIED

UNCLASSIFIED

Intro - 5

CATEGORY 5

LIQUID DENSITY

1. The word "liquid" is used in the title of this category merely to differentiate the category from category 12 which is entitled "relative vapor density". Actually, data on the density of solids as well as liquids are given in this category. Data referring to the solid phase of an agent have been marked with the word "solid" in parentheses.
2. Density data for each agent have been selected at the following temperatures: -40°F (or some temperature at which the agent is solid if its MP is above -40°F), 32° , 68° , and 160°F . These temperatures are also given in degrees centigrade in the body of the report.

UNCLASSIFIED

UNCLASSIFIED

Intro - 6

CATEGORY 6

SOLUBILITY IN ORGANIC SOLVENTS

An attempt has been made to gather as much information as possible on mixtures of each agent with other substances. The bibliography of this category for each agent, therefore, is made up not only of reports which contain solubility data on the agent in various organic solvents but reports which contain data of any kind (MP, density, vapor pressure, etc.) on mixtures of the agent as well.

UNCLASSIFIED

UNCLASSIFIED

Intro - 7

CATEGORY 7

SOLUBILITY IN WATER

1. A few of the agents covered in this document are gases under normal conditions. The solubility of a gas in a liquid is greatly dependent upon pressure. Solubility data for gases are usually given in terms of Bunsen or Oswald solubility coefficients. Definitions of these two quantities follow.
2. Bunsen coefficient - The Bunsen solubility coefficient for a gas in a given solvent is defined as the volume of the gas at STP* that can be dissolved in a unit volume of the solvent at a given temperature and pressure (partial pressure of the gas). The symbol that is usually used to designate the Bunsen coefficient is a small Greek sigma (σ).
3. Oswald coefficient - The Oswald solubility coefficient for a gas in a given solvent is defined as the ratio of the volume of absorbed or dissolved gas to the volume of absorbing liquid (or pure solvent) at a given temperature when the gas and solvent are in equilibrium. It may also be defined as the ratio of the concentration of gas in solution (weight per unit volume of pure solvent) to the concentration of gas in the vapor phase (weight per unit volume of gas) at a given temperature when the gas and solvent are in equilibrium. The Oswald coefficient is usually designated by "L".

$$L = \frac{V_g}{V_s} = \frac{C_s}{C_g}$$

where V_g and V_s = volume of dissolved gas and volume of pure solvent respectively, and

C_s and C_g = concentration of gas in solution and concentration of gas in the vapor phase respectively.

4. For more information on gas/solvent phenomena and the factors which alter them see Markham and Kobe, Chem. Rev. 28, 519 (1941).

* STP = standard temperature and pressure, 0°C and 760 mm Hg.

UNCLASSIFIED

UNCLASSIFIED

Intro - 8

CATEGORY 3

HYDROLYSIS

Provided sufficient data were available, the hydrolysis half-life of each agent in water of pH 7 at 20°C has been calculated.

UNCLASSIFIED

UNCLASSIFIED

Intro - 9

CATEGORY 9

EFFECTS OF HEAT AND BLAST

1. The data given in this category for each agent may be of any or all of the following types:
 - a. Flash point
 - b. Auto-ignition temperature
 - c. Inflammability limits of mixtures of the agent with air
 - d. Data on thermal decomposition.
 - e. Data on decomposition of the agent when disseminated explosively or by thermal generation.
2. Occasionally all that could be found in the literature concerning the thermal decomposition of an agent was a statement that it "decomposes rapidly" at such and such a temperature. By this and other similar, qualitative statements that are given for some of the agents in this document is meant that the agent shows noticeable decomposition after remaining at the specified temperature for anywhere from a few seconds to a few hours. Data which refer to the decomposition of the agent in storage over a period of several days to several years are given in category 10.
3. By "disseminated explosively" in item (e) of paragraph 1, above, is meant disseminated by filling explosive type munitions, such as shells and bombs, with the agent and functioning them. "Disseminated by thermal generation" refers to dissemination from smoke pots or candles and similar devices.

UNCLASSIFIED

UNCLASSIFIED

Intro - 10

CATEGORY 10

STABILITY IN STORAGE, ACTION ON METALS

1. As indicated in category 9, only data which refer to the decomposition of an agent in storage over a period of several days to several years are given in this category. Data on the "rapid" decomposition of an agent (within a few seconds to a few hours) are given in category 9.
2. In summarizing the information available in this category on those agents for which efficient stabilizers have been found, the phrase "for long periods of time" is used to describe the stability of the agent. This phrase is hereby defined to mean any period of time longer than one year.

UNCLASSIFIED

UNCLASSIFIED

Intro - 11

CATEGORY 11

LATENT HEAT OF VAPORIZATION

1. The latent heat of vaporization (ΔH) of each agent has been calculated at the agent's normal boiling point (BP), provided sufficient vapor pressure data were available in the vicinity of the BP to allow such a calculation. For those agents whose BP's do not lie between -40° and 71°C , the ΔH has also been calculated at 20°C .
2. The heat of vaporization (or sublimation) of a compound is usually calculated from vapor pressure data and the Clapeyron or Clausius-Clapeyron equation. At pressures of a few atmospheres or less the Clausius-Clapeyron equation, which follows, is usually used.

$$\frac{d(\ln p)}{d(1/T)} = \frac{-\Delta H}{R}$$

At very high pressures the more accurate Clapeyron equation should be used.

$$\frac{dp}{dT} = \frac{H}{T\Delta V}$$

Most of the values given in this document were calculated from either of these two equations.

3. In calculating the ΔH 's of those agents that are mixtures, experimental vapor pressure data were used whenever such data were available. In any case where experimental data were not available, the mixture was assumed to obey Raoult's law and the latent heat of vaporization was calculated accordingly.

UNCLASSIFIED

UNCLASSIFIED

Intro - 12

CATEGORY 12

RELATIVE VAPOR DENSITY

1. By "relative vapor density" in this document is meant the ratio of the weight of a unit volume of an agent's vapor to the weight of an equal volume of dry air at the same temperature and pressure.

$$\text{Relative vapor density} = \frac{\text{density of vapor at T and P}}{\text{density of air at T and P}}$$

In the chemical literature this ratio is also referred to as a compound's "vapor density relative to air" or simply "vapor density (air = 1)".

2. At ambient temperatures and at pressures of about one atmosphere or less most agents do not depart appreciably from the ideal gas law. Their relative vapor densities therefore may be calculated from the following simple relationship which is easily derived from the ideal gas law.

$$\text{Relative vapor density} = \frac{\text{MW}}{28.96}$$

where MW = the molecular weight of the agent and
28.96 = the mean molecular weight of air.

All of the relative vapor densities given in this document (excepting those for AC) were calculated from the above equation. Each has been marked with the words "theoretical value" in parentheses.

UNCLASSIFIED

UNCLASSIFIED

Intro - 13

CATEGORY 13

VAPOR PRESSURE

1. Vapor pressure data have been selected for each agent at the following temperatures: -40° , 0° , 32° , 68° , 125° , and 160° F. These temperatures are also given in degrees centigrade in the body of the report.
2. All values for the vapor pressure of the solid phase of an agent have been marked with a small "s" in parentheses.
3. Values that have been selected for those agents that are mixtures were taken from experimental data whenever such data were available. In cases where experimental data were not available, the mixtures were assumed to obey Raoult's law and the desired values were calculated accordingly.

UNCLASSIFIED

UNCLASSIFIED

Intro - 14

CATEGORY 14

VOLATILITY IN ATMOSPHERIC AIR

1. Volatility values have been calculated for each agent at the following temperatures: -40° , 0° , 32° , 68° , 125° , 160° F and the agent's normal boiling point (BP). All values given at temperatures below an agent's BP have been calculated from the vapor pressure data that were selected for the agent at these temperatures in category 13. All values given at temperatures above an agent's BP (including the BP) have been calculated at atmospheric pressure (760 mm Hg). The data have been presented in this rather unorthodox fashion for a number of practical reasons, the most important of which is to facilitate comparison of an agent's toxicity by inhalation to its volatility (or maximum vapor density) under normal ambient conditions.
2. All volatility values (excepting those for AC) have been calculated from the ideal gas law, $PV = nRT$.
3. Of interest is the fact discovered by Hoffman that the rate of evaporation of a compound at a given temperature is approximately proportional to the product of the compound's vapor pressure at that temperature and its molecular weight.

$$R_{\text{evap.}} = K. (p.) (MW)$$

For further information see Hoffman, Ind. Eng. Chem. 24, 135 (1932).

UNCLASSIFIED

UNCLASSIFIED

Intro - 15

CATEGORY 15

ODOR AND MEDIAN DETECTABLE CONCENTRATION

This category contains information on:

- a. Description of odor
- b. Median detectable concentration (DC_{50}) by odor, or by irritation of nose, throat, eyes, or skin.

UNCLASSIFIED

UNCLASSIFIED

Intro - 16

CATEGORY 16

TOXICITY BY INHALATION

This category contains information on:

- a. Median lethal exposure (LC₅₀).
- b. Median incapacitating exposure (IC₅₀).
- c. Whether or not the agent is toxic or irritating to the respirating tract.
- d. Data on chronic toxicities.

UNCLASSIFIED

UNCLASSIFIED

Intro - 17

CATEGORY 17

EYE TOXICITY

This category contains information on:

- a. Median lethal and incapacitating doses (LD₅₀ and ID₅₀) for liquid agent.
- b. Median lethal and incapacitating exposures (LCt₅₀ and ICt₅₀) for vapor agent.
- c. Whether or not the agent affects the eyes or poisons system after entry into the body through the eyes.

UNCLASSIFIED

UNCLASSIFIED

Intro - 18

CATEGORY 18

ORAL TOXICITY

This category contains information on:

- a. Median lethal dose (LD₅₀).
- b. Median incapacitating dose (ID₅₀).

UNCLASSIFIED

UNCLASSIFIED

Intro - 19

CATEGORY 19

SKIN TOXICITY AND CLOTHING PENETRATION

This category contains information on:

- a. Median lethal and incapacitating doses (LD_{50} and ID_{50}) for liquid agent.
- b. Median lethal and incapacitating exposure (LCt_{50} and ICt_{50}) for vapor agent.
- c. Whether or not agent affects skin or poisons system after penetration of skin.
- d. Special type of clothing necessary for adequate protection.

UNCLASSIFIED

UNCLASSIFIED

Intro - 20

CATEGORY 20

SPEED OF ACTION

This category contains information on:

- a. Average time required to incapacitate victim.
- b. Average period of incapacitation.

UNCLASSIFIED

UNCLASSIFIED

Intro - 21

CATEGORY 21

DETOXICATION IN THE BODY

This category contains information on:

- a. Rate of detoxication
- b. Route of entry if rate depends thereupon.

UNCLASSIFIED

UNCLASSIFIED

Intro - 22

CATEGORY 22

MEDICAL PROTECTIVE OR FIRST AID MEASURES

This category contains information on:

Practical protective or first aid measures that are effective against the agent such as ointments, medicinals, etc.

UNCLASSIFIED

UNCLASSIFIED

Intro - 23

CATEGORY 23

DETECTION

This category contains information on:

The latest and most effective means of detecting the specific agent, the type of kit, the items in the kit (vials, papers, etc.) that are used, the color change or noticeable reactions that take place, brief description of the chemistry involved.

UNCLASSIFIED

UNCLASSIFIED

Intro - 24

CATEGORY 24

INDIVIDUAL PROTECTION

This category contains information on:

The type of mask, canister, clothing which should be used to protect an individual against the agent and their relative effectiveness.

UNCLASSIFIED

UNCLASSIFIED

Intro - 25

CATEGORY 25

DECONTAMINATION

This category contains information on:

The types of decontamination - decontamination of leaking munitions in storage and decontamination in the field. For some agents the two will be considerably different. The cheapest and most effective means of decontaminating areas of this agent are considered.

UNCLASSIFIED

SECRET

GA-1

GA - TABUN (German)

CATEGORY 1

SECONDARY SOURCES OF INFORMATION ON GA

Readers desiring information on GA which is beyond the scope of this document may find the following works of great value.

With Bibliography

ETF 100.25 (1948)
ETF 107-3 (1946)
ETF 107-7 (1946)
ETF 550E-8327 (1951)
MDR 159 (1948)
MLSR 23 (1953)
Porton Memo 35 (1950)
TCIR 481 (1949)

Without Bibliography

PR 2747 (1947)

SECRET

SECRET

GA-2

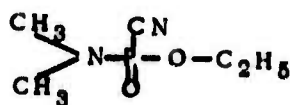
CATEGORY 2

NAME, FORMULA, MOLECULAR WEIGHT

A. Bibliography

None

B. Summary

- | | |
|----------------------|---|
| 1. Technical Name: | Ethyl dimethylphosphoramidocyanidate or
Cyanodimethylaminoethoxyphosphine |
| 2. Common name: | Tabun (German) |
| 3. Chemical formula: | $C_5H_{11}N_2O_2P$ or  |
| 4. Molecular weight: | 162.13 |

C. Discussion

This compound may also be found in the classified literature under the following code names and numbers:

MCE
T-2104 (British)
TL-1578 (UCTL)
T-83 (German)
Le 100 (German)
FM-511

SECRET

SECRET

GA-3

CATEGORY 3

**PHYSIOLOGICAL ACTION, TACTICAL USE, STATUS
RUSSIAN INTEREST**

A. Bibliography

1. Air Intelligence Digest, Vol. 4, No. 8 (August 1951)
2. ETF 550R-911 (1951)

B. Summary

1. Physiological action:

Nerve gas

2. Tactical use:

GA may be used as a non-persistent spray or persistent ground contaminant. It is very effective in producing immediate casualties.

3. Status:

Limited standard

4. Russian interest:

The Russians have great interest in GA as a warfare agent. They are known to have captured a full-scale GA plant upon the invasion of Germany during World War II. At the present time, they are considered to have limited stockpiles of the agent and are probably producing it at an appreciable rate (A1, A2).

SECRET

SECRET

GA-4

CATEGORY 4

PHYSICAL STATE, MELTING POINT, BOILING POINT

A. Bibliography and Data

1. CD Report 5/IS 73 (A. 2156) (1945)
Ptn. 4240 (V. 3956) (1945)

BP = 230°C (with decomposition)

2. 44th Chem. Lab. CMTR 60 (1945)

BP = 220°C

3. Suffield Technical Minute 109 (1945)

MP = -48.9° ± 0.3°C

4. TDMR 1094 (1945)

Sample #1 FP = -51.0°C (1st determination)
 FP = -50.8°C (2nd determination)

Sample #2 FP = -50.0°C (1st determination)
 FP = -50.0°C (2nd determination)

Sample #2 appeared to be the purer of the two.

BP = 246°C (calculated; see category 13)

5. ETF 550F-154 (1949)

BP = 220°C

The following report contains freezing point data on various mixtures of GA with other compounds:

6. ETF 550G-1260 (1944)

GA/DA
GA/DC

B. Summary of Data and Selected Values

1. Physical state:

Pure GA is a colorless liquid of low volatility at room temperature.

SECRET

2. Freezing point:

-50°C (-58°F)

3. Normal boiling point:

Compound begins to decompose rapidly at about 160°C (300°F).
Theoretical BP: 220° to 240°C (430° to 465°F) (obtained by
extrapolation of vapor pressure data).

4. GA of plant purity has the following characteristics:

Amber to brown in color.

FP below -50°C (-58°F)

C. Discussion

Suffield Technical Minute 102 (A3) and TDMR 1094 (A4) contain the only data on the FP of GA that are available. Neither report gives sufficient information on the methods of determination employed to warrant selection of any of the values reported as the one which best represents the true FP of GA. The FP given in (B2) therefore was selected as an average of the data contained in both reports. It is probably accurate within a degree or two.

SECRET

GA-5

CATEGORY 5

LIQUID DENSITY

A. Bibliography and Data

1. CD Report 5/16 73 (A. 2156) (1945)
Ptn. 4240 (V. 3956) (1945)

Sp. Gr. = 1.056 at 22°C (H₂O at 22°C)

d = 1.054 g/cm³ at 22°C

2. 44th Chem. Lab. CMTR 60 (1945)

d = 1.059 g/cm³ at 18°C

3. NDRC Inf. Rept. 9-4-1, NS 2 (1945)

d = 1.0762 g/cm³ at 20°C

This value also appears in NDRC Inf. Rept. 9-4-1, NS 3 (4).

4. NDRC Inf. Rept. 9-4-1, NS 3 (1945)

Sample #1 d = 1.0762 g/cm³ at 20°C

Sample #2 d = 1.0767 g/cm³ at 20°C

Sample #3 d = 1.1200 g/cm³ at 20°C

Sample #4 d = 1.0847 g/cm³ at 20°C

The following two values are given in a different section of the report:

d = 1.076 g/cm³ at 23°C

d = 1.077 g/cm³ at 23°C

They appear to be the same values as those reported for samples #1 and #2 above. The temperatures are different, however. No explanation is given - perhaps a typographical error.

5. Suffield Technical Minute 109 (1945)

Sample #1 d: from 1.1617 g/cm³ at -50°C
to 1.0618 g/cm³ at 50°C (16 values)

Sample #2 d: from 1.1485 g/cm³ at -50°C
to 1.0515 g/cm³ at 50°C (16 values)

Sample #2 was considered to be the purer of the two.

SECRET

SECRET

GA-5

6. TDMR 1094 (1945)

$d = 1.0869 \text{ g/cm}^3$ at 9.80°C
 1.0731 g/cm^3 at 24.9°C
 1.0636 g/cm^3 at 35°C

7. TDMR 1121 (1945)

$d = 1.076 \text{ g/cm}^3$ at 20°C

This value also appears in TDMR 1138 (8).

8. TDMR 1138 (1945)

Sample #1	$d = 1.080 \text{ g/cm}^3$ at 20°C
Sample #2	$d = 1.078 \text{ g/cm}^3$ at 20°C
Sample #3	$d = 1.078 \text{ g/cm}^3$ at 20°C
Sample #4	$d = 1.079 \text{ g/cm}^3$ at 25°C
Sample #5	$d = 1.086 \text{ g/cm}^3$ at 25°C
Sample #6	$d = 1.082 \text{ g/cm}^3$ at 25°C

Sample #1 was considered to be the purest of the lot.

9. ETP 550F-154 (1949)

$d = 1.094 \text{ g/cm}^3$ at 17.25°C
 1.077 g/cm^3 at 20°C

The following reports contain density data on mixtures of GA with other compounds:

10. ETP 550G-1260 (1944)

80% GA/20%DC	$d = 1.125 \text{ g/cm}^3$
40% GA/60%DC	$d = 1.243 \text{ g/cm}^3$

11. 44th Chem. Lab. CMTR 60 (1945)

85 to 90% GA/10 to 15% monochlorobenzene $d = 1.081 \text{ g/cm}^3$
at 18°C

12. TDMR 1094 (1945)

95% GA/5% monochlorobenzene $d = 1.1001 \text{ g/cm}^3$ at 9.8°C
 1.0864 g/cm^3 at 24.9°C
 1.0771 g/cm^3 at 35°C

SECRET

B. Selected Values

Liquid density:

1. 1.139 g/cm³ at -40°C (-40°F)
2. 1.100 g/cm³ at 0°C (32°F)
3. 1.080 g/cm³ at 20°C (68°F)
4. 1.031 g/cm³ at 71°C (160°F)

GA of plant purity usually has a density of:

5. 1.09 to 1.11 g/cm³ at 0°C (32°F)
6. 1.07 to 1.09 g/cm³ at 20°C (68°F)

C. Discussion

Suffield Technical Minute 109 (A5) contains what appear to be the best data on the density of GA that are available. These data were plotted on a density-temperature graph and values (B1) through (B4) were obtained therefrom by either interpolation or extrapolation. Although the data in the original report are given to five significant figures, they are probably not accurate to more than four. The values in paragraph B therefore are given to four significant figures.

SECRET

GA-6

CATEGORY 6

SOLUBILITY IN ORGANIC SOLVENTS

A. Bibliography and Data

1. ETF 550G-1260 (1944)

GA/DA	GA/MD
GA/DC	GA/PD
GA/AC	GA/CG
GA/CK	GA/chlorobenzene
GA/H	GA/ carbon monoxide

2. TDMR 1299 (1946)

GA/HD

3. PR 2747 (1947)

GA is soluble in all common organic solvents

4. ETF 550F-154 (Translation) (1949)

GA is soluble in monochlorobenzene

5. MDR 184 (1949)

GA/ethyl carbitol
GA/butyl carbitol
GA/tetralin

6. CRLR 322 (1954)

GA/CX

B. Summary of Data

GA is readily soluble in almost all common organic solvents.

SECRET

SECRET

GA-7

CATEGORY 7

SOLUBILITY IN WATER

A. Bibliography and Data

1. CDR 5/IS 73 (A. 2156) (1945)
Ptn 4240 (V. 3956) (1945)

GA is soluble in water to the extent of two to three percent.

2. Suffield Tech. Minute 109 (1945)

Solubility = 8.2g GA/100 ml solution at 0°C

3. ETF 660-6/Final (1946)

Solubility = 10.86g GA/100 ml solution at 25°C

4. 2d Ind, CMLRE-CR(CP), Proj 4-08-03-005, CmlC Cml and Rad Labs to CmlC Research and Engineering Command, 12 Jun 1952, subject: "Water Solubility of G-Agents," on letter, CMLEK-A, Chemical Corps Board, 29 Apr 1952.

Solubility = 9.8g GA/100g solution at 0°C
7.2g GA/100g solution at 20°C

B. Summary of Data

The solubility of GA in water is 72g GA/1000g solution at 20°C (68°F)

C. Discussion

The value given in paragraph B was taken from the letter from CmlC Cml and Rad Labs to CmlC research and Engineering Command, CmlC (A4), which contains the best data available on the solubility of GA in water.

SECRET

SECRET

GA-8

CATEGORY 8

HYDROLYSIS

A. Bibliography and Data

1. CD Report 5/IS 73 (A. 2156) (1945)
Ptn 4240 (V. 3956) (1945)
2. TDMR 1121 (1945)

At 25°C: from pH 1, $t_{1/2}$ = 4140 min.
to pH 11, $t_{1/2}$ = 5 min. (9 values)
3. ETF 550E-6092 (1947)

At 37°C: pH 5.0, k = 0.00385 per min. per mol liters

At 37°C: pH 7.4, k = 0.00545 per min. per mol liters
4. MDR 127 (1947)
5. Porton Tech. Paper 85 (1948)

 k : from 0.0167 per min. at pH 2.0 at 12°C
to 0.307 per min. at pH 10.0 at 37°C (30 determinations)
6. Porton Tech. Paper 150 (1950)

 k = $1.14 \cdot 10^{-2}$ per min. at 15°C at pH 11.3
 $2.72 \cdot 10^{-2}$ per min. at 25°C at pH 11.3
7. ETF 100-29/Final (Task 9) Vol. 1, 30 April (1954)
ETF 100-29/Final (Task 9) Vol. 2, 30 April (1954)

B. Selected Value

At 20°C (68°F) and pH 7.0, the half-life of hydrolysis of GA is 8.5 hours.

C. Discussion

This value was taken from the data of the report Porton Tech. Paper 85 (A5). These data were performed over a wide range of pH and temperature. The value is the result of a neutral hydrolysis of GA producing HCN. It can be seen that GA reacts slowly with water and fairly rapid with strong acids and alkalis with self-buffering at pH 4.5 (A2).

SECRET

SECRET

GA-9

CATEGORY 9

EFFECTS OF HEAT AND BLAST

A. Bibliography

1. TDMR 132 (1945)
2. Porton Technical Paper 46 (1948)
3. Ptn./IL. 2101/3535/50 (1950)
4. Krecke and DiPaola, CRLR report in preparation, Project 4-04-15-007, subject: Status Report, Dissemination of Toxic Agents by Thermal Generation (1954 or later).

B. Summary of Data

GA is inflammable in air. Its closed-up flash point in atmospheric air (760 mm Hg) is 172°F (78°C) (A2).

The thermal decomposition of GA is probably similar to that of the other G-agents. Complete decomposition takes place within about three hours at about 150°C (300°F) (A1).

GA undergoes considerable decomposition when disseminated explosively or disseminated by thermal generation (A3, A4).

SECRET

SECRET

GA-10

CATEGORY 10

STABILITY IN STORAGE, ACTION ON METALS

A. Bibliography

1. TDMR 1299 (1946)
2. PR 2747 (1947)
3. ETF 550E-7069 (1948)
ETF 550E-7473 (1949)
ETF 550E-7683 (1950)
ETF 550E-8086 (1951)
ETF 550E-8377 (1953)

B. Summary of Data

Most of the GA that the United States has on hand is captured German material containing anywhere from 5 to 20% monochlorobenzene. This material is stable in steel for several years (A3), but has been found to undergo complete decomposition (as judged from distillation data) within three months at 65°C (150°F) (1).

The corrosion rate of German GA (5 to 20% monochlorobenzene) on steel has been found to be 3.4×10^{-5} inches penetration per month at 65°C (150°F)(A1).

SECRET

SECRET

GA-11

CATEGORY 11

LATENT HEAT OF VAPORIZATION

A. Bibliography and Data

1. A. 3804/3 (1945)
Porton Technical Paper 341 (1953)

$$\Delta H_{\text{vap}} = 17.2 \text{ kcal/mol at } 25^{\circ}\text{C}$$

2. TDMR 1094 (1945)

$$\Delta H_{\text{vap}} = 12.9 \text{ kcal/mol at } 35^{\circ} \text{ to } 95^{\circ}\text{C}$$

B. Selected Value

Latent heat of vaporization at 20°C (68°F):

$$16 \text{ kcal/mol (100 cal/g)}$$

C. Discussion

The value selected in paragraph B was calculated from the vapor pressure data of Porton Technical Paper 341 (A1) and MIT-MR 163 (category 13, para A, item 5). These two reports contain the best data available on the vapor pressure of GA at temperatures around 20°C (see category 13, para C). Values for the ΔH of GA were calculated from the data of both reports using the Clausius-Clapeyron equation. The result obtained from the Porton data is given in the bibliography (A1); a ΔH of 15.2 kcal/mol was obtained from the MIT data. The value given in paragraph B was selected as an average of these two values.

SECRET

SECRET

GA-12

CATEGORY 12

RELATIVE VAPOR DENSITY*

A. Bibliography

None

B. Selected Value

Relative vapor density: 5.60 (theoretical value)

*Relative vapor density = $\frac{\text{density of vapor at T and P}}{\text{density of air at T and P}}$

SECRET

SECRET

GA-13

CATEGORY 13

VAPOR PRESSURE

A. Bibliography and Data

1. A. 3804/3 (1945)
Porton Technical Paper 341 (1953)

By effusion manometer -

p: from 0.0274 mm Hg at 17°C
to 0.0938 mm Hg at 30°C (6 determinations)

The following equation was derived from the above data by the method of least squares:

$$\log p = 11.345 - \frac{3750}{T} \quad (\text{range: } 17^{\circ} \text{ to } 30^{\circ}\text{C})$$

(273.2°K = 0.0°C)

2. CD Report 5/IS 73 (A. 2156) (1945)
Ptn. 4240 (V. 3956) (1945)

p = 1.6 mm Hg at 93°C
10 mm Hg at 120°C
760 mm Hg at 230°C

The following value was reported for a German sample. It also appears in TDMR 1138 (12).

p = 2 mm Hg at 93°C

3. 40th Chem. Lab. Co., Monthly Intelligence Report, 1 April to 30 April 1945

p = 2 mm Hg at 84° to 89°C
4 mm Hg at 95° to 98°C

4. 44th Chem. Lab. CMTR 60 (1945)

p = 6 mm Hg at 98°C
760 mm Hg at 220°C

5. MIT-MR 163 (1945)

Sample was fractionally distilled three times. Final distillation yielded -

SECRET

SECRET

GA-13

$p = 2$ to 3 mm Hg at 78° to 80°C

Distillate was used to obtain the following data (transference method) -

$p = 0.038$ mm Hg at 20°C
0.097 mm Hg at 30°C
0.210 mm Hg at 40°C

6. NDRC Inf. Rept. 9-4-1, NS 2 (1945)

$p = 4$ mm Hg at 87° to 88°C

7. NDRC Inf. Rept. 9-4-1, NS 3 (1945)

Sample was distilled into four fractions. Following data were obtained:

$p = 85$	mm Hg at 155°C	(1st fraction)
25.5	mm Hg at 121°C	(2nd fraction)
7	mm Hg at 98° to 99°C	(3rd fraction)
5	mm Hg at 94° to 103°C	(4th fraction)

These data were used to derive the following equation:

$$\log p = 9.11287 - \frac{3071.8}{T} \quad (\text{range } 94^{\circ} \text{ to } 155^{\circ}\text{C})$$

The following distillation values were obtained on two other samples:

$p = 2$ mm Hg at 89° to 92°C
0.25 to 0.3 mm Hg at 56° to 58°C

8. OSRD 6391 (1945)

Sample was distilled into two fractions. Purest fraction yielded

$p = 3$ mm Hg at 88° to 98°C

9. Suffield Technical Minute 109 (1945)

Sample was fractionally distilled three times. Final distillation yielded -

$p = 0.2$ mm Hg at 52°C

SECRET

10. TDMR 1094 (1945)

By transference method (two different samples) -

p: from 0.0454 mm Hg at 25.0°C
to 0.573 mm Hg at 55.0°C (14 determinations)

By Ramsey-Young method -

p = 1.15 mm Hg at 68.9°C
3.7 mm Hg at 93.3°C

By vacuum distillation (these two values also appear in
TDMR 1138 (12)) -

p = 1.5 mm Hg at 72.5° to 73°C
3 mm Hg at 86° to 87°C

The following equation was derived from the above data by the
method of least squares:

$$\log p = 8.305 - \frac{2820}{T} \quad (\text{range: } 25^\circ \text{ to } 94^\circ \text{C})$$

11. TDMR 1132 (1945)

Sample was distilled into three fractions. Purest fraction yielded

p = 2 mm Hg at 70° to 72°C

12. TDMR 1138 (1945)

Distillation data were obtained on six different samples. Two
purest samples yielded -

p = ca. 1.5 mm Hg at 72.5° to 73°C (Sample #1)
3 mm Hg at 86° to 87°C (Sample #2)

The following value was obtained on a German sample:

p = 2 mm Hg at 93°C

13. ETF 550F-154 (1949)

p: 2 mm Hg at 67°C to 67°C
760 mm Hg at 220°C (8 determinations)

14. Porton Technical Paper 204 (1950)

Sample fractionally distilled twice. Second distillation yielded

$p = 0.5 \text{ mm Hg at } 65^{\circ}\text{C}$

15. Porton Technical Paper 335 (1953)

Sample contained radioactive phosphorous (P_{32})

$p = 2 \text{ mm Hg at } 100^{\circ}\text{C}$

B. Selected Values

Vapor pressure:

- (1) 0.006 mm Hg at 0°C (32°F)
- (2) 0.037 mm Hg at 20°C (68°F)
- (3) 0.4 mm Hg at 52°C (125°F)
- (4) 2 mm Hg at 71°C (160°F)

C. Discussion

The vapor pressure data available for GA are very inconsistent. Porton Technical Paper 341 (A1) and MIT-MR 163 (A5) contain what appear to be the most precise data that have been reported to date. The data of these two reports are in agreement roughly to about two significant figures. This is true only because the data lie within a narrow temperature range (17° to 40°C), however. The slopes of the two sets of data, when plotted on a $\log p$ vs. $1/T$ graph, were found to be different and extrapolations of the data diverge rapidly.

TDMR 1094 (A 10) contains the only other data that have been produced with any precision. These data, when plotted, have a slope that differs considerably from the slopes of the two previously mentioned sets of data. Of the three reports cited so far, however, only the TDMR report contains data which are in good agreement with the large mass of distillation data that have been reported for GA. The Porton data, which exhibit a comparatively steep slope, fail to agree with any of the distillation data when extrapolated. And extrapolation of the MIT data results in agreement with only the comparatively high distillation data of ETF 550F-154 (A 13).

Because of these inconsistencies, it was decided to plot all of the data available on a $\log p$ vs. $1/T$ graph and to select the desired values from the resulting composite of the data. Values (B1) and (B2) therefore are based upon the data of Porton Technical Paper 341 and MIT-MR 163, value (B3) upon the data of TDMR 1094 and distillation data and value (B4) entirely upon distillation data. Each value is given to the number of significant figures which the data from which the value was taken would allow.

No values were obtained at temperatures below 0°C because of the lack of data.

SECRET

SECRET

GA-14

CATEGORY 14

VOLATILITY IN ATMOSPHERIC AIR

A. Bibliography

None

B. Selected Values

Volatility in atmospheric air:

(1)	$0.06 \times 10^3 \text{ mg/m}^3$	at 0°C (32°F)	(0.006 mm Hg)
(2)	$0.33 \times 10^3 \text{ mg/in}^3$	at 20°C (68°F)	(0.037 mm Hg)
(3)	$3 \times 10^3 \text{ mg/m}^3$	at 52°C (125°F)	(0.4 mm Hg)
(4)	$15 \times 10^3 \text{ mg/m}^3$	at 1°C (160°F)	(2 mm Hg)

SECRET

SECRET

GA-15

CATEGORY 15

ODOR AND MEDIAN DETECTABLE CONCENTRATION

A. Bibliography

1. Medical Division Informal Monthly Report (1945)
2. Porton Report 4240 (V. 6912) (1945)
3. Porton Memo 39 (1950)

B. Discussion

1. Odor of GA is fruity or sweet (A2, A3).
2. Median detectable concentration is 2.2 $\mu\text{g/l}$ (2.2 mg/m^3) (A1).

SECRET

SECRET

GA-16

CATEGORY 16

TOXICITY BY INHALATION

A. Bibliography

MDR 201 (1949)

B. Discussion

1. Median lethal exposure is 500 mg. min/m³ for a 10 minute exposure.
2. Median incapacitating exposure is 100 mg. min/m³ for a 10 minute exposure.
3. GA causes bronchoconstriction.
4. There is no data on chronic toxicities.

SECRET

SECRET

GA-17

CATEGORY 17

EYE TOXICITY

A. Bibliography

1. Porton Report 2698 (1946)
2. Porton Memo 39 (1950)

B. Discussion

Vapor applied directly and only to the eyes:

0.7 mg. min/m³ (t = 2 minutes) - no eye effects
3.2 mg. min/m³ (t = 2 minutes) - slight but definite effects.

14-21 mg. min/m³ - severe harassing effects for several days.

30 mg. min/m³ (t = 10 minutes) - very severe harassing to only one subject (visual acuity reduced for 17 days) (A1).

The eye effects produced by exposure to low dosages of nerve gas are manifestly due to local action of the vapor on the eye, since they occur to the same extent in men whose respiratory passages are protected by oronasal respirators as in unprotected men, and do not result if the observers wear close-fitting goggles but are otherwise unprotected. Threshold eye symptoms with 0.9 mg. min/m³ (t = 5 minutes). Moderate harassment for 3 to 5 days with 2.5 to 4 mg. min/m³ (t = 10 to 20 minutes).

SECRET

SECRET

GA-18

CATEGORY 1A

ORAL TOXICITY

No man data found.

SECRET

SECRET

GA-19

CATEGORY 12

SKIN TOXICITY AND CLOTHING PENETRATION

A. Bibliography

1. RTF 550G-1736
2. MDR 201 (1949)

B. Discussion

1. Based on rabbit data ($LD_{50} = 3.3$ mg per Kg body weight) an approximate LD_{50} of 0.23 grams/70 kg man is estimated (A2).

No data for incapacitating exposure for liquid GA.

One drop on the skin, especially on the face, must be regarded as fatal (A1).

2. With the lungs and eyes protected and the body exposed:

The median lethal exposure is 20,000 mg.min/m³ (time exposure of 10 minutes)

the median incapacitating exposure is 12,000 mg.min/m³ (time exposure of 10 minutes).

3. Agent affects system after absorption through skin.
4. Impermeable protective clothing is required for protection.

SECRET

SECRET

GA-20

CATEGORY 20

SPEED OF ACTION

A. **Bibliography**

MDR 201 (1949)

B. **Discussion**

Incapacitation will occur within 1 hour after exposure to agent.

SECRET

SECRET

GA-21

CATEGORY 21

DETOXICATION IN THE BODY

No man data found.

SECRET

SECRET

GA-22

CATEGORY 22

MEDICAL PROTECTIVE OR FIRST AID MEASURES

A. Bibliography

TM 8-285, Treatment of Chemical Warfare Casualties

B. Discussion

In the treatment of GA casualties, speed of treatment is of the essence. Casualties should be removed from possibility of further contamination if possible and given an immediate injection of atropine and subjected to artificial resuscitation. Present thought is that atropine injection alone, while helpful in cases of mild exposure, is of little value in more severe exposure unless artificial resuscitation is applied. Either of these treatments alone is helpful but the combination of the two has more than the additive value. Thorough familiarization with the subject in reference TM-285 is strongly recommended. For skin contamination, wash with sodium bicarbonate and test as above. In the eyes and mouth, wash with 3% bicarbonate.

SECRET

SECRET

GA-23

CATEGORY 23

DETECTION

A. Bibliography

1. FM 21-40, Defense Against Chemical Attack.
2. Instructions - Kit, Chemical Agent Analyzer, M10A1, use of (27 April 1954)
3. Instructions - Kit, Chemical Agent Detector, M9A2.
4. Instructions - Kit, Water Testing, Poisons M-2 (14 July 1952).
5. TM 3-215, Military Chemistry and Chemical Agents.
6. TM 3-290, Individual Protective and Detection Equipment.
7. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Objectively, GA is detected by:

- (1) Detector kit (M9A2). A greenish-blue ring appears in white dot tube after wetting with solution from green top bottle. (Note: this is a general test and will be positive for G-agents and/or CK) (A3).
- (2) Analyzer kit (M10A1). The standard test (A2) which contains granules from a white dot tube which are treated first with a solution of O-DN and then a solution of PER. An orange or amber color in the solution indicates the presence of G-agents (or CK). The white dot tube turns red-purple when wet with an alcoholic solution of Chlor-T and then an alcoholic solution of gamma-picoline and PYR. (Note: This test indicates GA or CK).
- (3) An alternate or confirmatory test (A2) which contains plain strips of filter paper which can be impregnated with Chlor-T in advance and when held in close contact with a strip of filter paper, one end of which is wet with an alcoholic solution of gamma-picoline and PYR will result in the appearance of a red to purple spot on the newly wet paper. (Note: This test also indicates AC or CK).
- (4) Water testing and screening (AN-M2). Nerve gases are detected by a color reaction and extraction of the color by an immiscible solvent (A7).

SECRET

SECRET

GA-23

- (5) Water testing kit, poisons (M4). This kit enables quantitative determination of G-agents (A4).
- (6) Food testing and screening (ABC-M3). The nerve gases are identified by their reaction with two special chemicals to produce an orange or yellow color (A7).
- (7) Vesicant detector crayon (M7, M7A1). Drops of liquid G-agent cause pink crayon markings or dust to turn yellow (A6).
- (8) Liquid vesicant detector paint (M5). Surfaces painted with detector paint show a change in color from olive green to red when contaminated by drops or splashes of G-agents (A6).
- (9) Liquid vesicant detector paper (M6) (A6).

Subjectively, GA is detected by:

- (1) Odor - faint, sweetish, fruity (A5, A7).
- (2) Physical appearance - a colorless to brownish liquid (A5, A7).
- (3) Physiological symptoms - vapors may cause nausea, vomiting, and diarrhea followed by muscular twitching and convulsions. Even in low concentrations, vapor causes pupils to contract, vision becomes difficult in dim light, and headaches may result. A sense of tightness in the chest may be noticed. Contraction of the pupils may not appear as a warning sign of liquid penetration (A5, A7).

SECRET

SECRET

GA-24

CATEGORY 24

PROTECTION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents.
2. TM 3-290, Individual Protective and Detection Equipment.
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Protection against GA may be afforded by use of the protective mask. Impermeable protective clothing is required for protection against liquid G-agents (A1, A3). Protective dubbing is also used (A2).

SECRET

SECRET

GA-25

CATEGORY 25

DECONTAMINATION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents.
2. TM 3-220, Decontamination.
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

For personnel, soap and water, rather than protective ointment, are used for removing liquid contamination. Immediate and thorough action is necessary in removing nerve gases (2). The following fluids are more satisfactory than soap and water and should be used if available:

- (1) A slurry of one part of bleach in three parts of water.
- (2) A five to ten per cent solution of sodium carbonate.
- (3) A five to ten per cent solution of ammonium hydroxide.
- (4) A two per cent solution of sodium hydroxide.

If water alone is available, blot the excess liquid off the skin, then soak a fresh cloth with water and scrub the area turning the cloth with each bit of scrubbing to expose a clean surface. If a splash of liquid nerve gas should get into the eye, it should be flushed out immediately with water (A3).

For materiel and areas, in the case of liquid contamination, aeration, hot soapy water, bleach slurry, and solutions of commercially available alkalis, such as caustic soda and soda ash, are effective (A2). In confined areas, steam and ammonia are effective (A1).

SECRET

SECRET

GB-1

GB - SARIN (German)

CATEGORY 1

SECONDARY SOURCES OF INFORMATION ON GB

Readers desiring information on GB which is beyond the scope of this document may find the following works of great value.

With Bibliography

ETF 100.25 (1948)
ETF 107-3 (1946)
ETF 550E-7665 (1949)
ETF 550E-8327 (1951)
MDR 159 (1948)
MLSR 23 (1953)
Porton Memo 35 (1950)
TCIR 481 (1949)
TCR 36 (1949)

Without Bibliography

PR 2747 (1947)

SECRET

SECRET

GB-2

CATEGORY 2

NAME, FORMULA, MOLECULAR WEIGHT

A. Bibliography

None

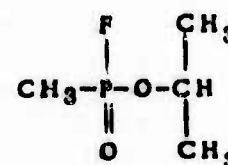
B. Summary

1. Technical name: Isopropyl methylphosphonofluoridate or Fluorisopropoxymethylphosphine oxide
2. Common name: Sarin (German)

3. Chemical formula:

$C_4H_{10}FO_2P$

or



4. Molecular weight:

140.11

C. Discussion:

This compound may also be found in the classified literature under the following code names and numbers:

MFI
EA 1208
T-2106 (British)
TL 1618 (UCTL)
T-144 (German)

SECRET

SECRET

GB-3

CATEGORY 3

**PHYSIOLOGICAL ACTION, TACTICAL USE, STATUS
RUSSIAN INTEREST**

A. Bibliography

1. Air Intelligence Digest, Vol. 4, No. 8 (August 1961)
2. ETF 550R-911 (1961)

B. Summary

1. Physiological action:

Nerve gas

2. Tactical use:

GB is usually disseminated as a non-persistent spray. It is very effective in producing immediate casualties.

3. Status:

Standard

4. Russian Interest:

The Russians have great interest in GB as a warfare agent. They are known to have captured a GB pilot plant upon the invasion of Germany during World War II. At the present time, they are considered to have limited stockpiles of the agent and are probably producing it at an appreciable rate (A1, A2).

SECRET

SECRET

GB-4

CATEGORY 4

PHYSICAL STATE. MELTING POINT. BOILING POINT

A. Bibliography and Data

1. TDMR 1163 (1946)

Sample did not freeze at -70°C .

BP = 147°C (calculated; category 13)

2. Chemical Corps Quarterly Report, Project 4-08-03-05, 1 January 1948

FP = $-58^{\circ}\pm 1^{\circ}\text{C}$

3. TCIR 513 (1949)

Sample #1 (distilled)

FP = -56.8°C

MP = -56.2°C

Sample #2 (singly crystallized)

FP = -56.7°C

Sample #3 (triply crystallized)

FP = -56.9°C

Sample #4 (filtrate after one crystallization) FP = -56.9°C

By FP in this report is meant the highest temperature to which the sample rose after supercooling.

4. CRLR 2 (1951)

Sample #1 (distilled)
(crystals)
(filtrate)

FP = -57.0°C

FP = -56.85°C

FP = -56.83°C

Sample #2 (crystals)
(filtrate)

FP = -57.2°C

FP = -57.6°C

Sample #3 (crystals)

FP = -57.2°C

The following reports contain data on mixtures of GB with other compounds:

5. ETF 550-936 (1953)

65% GB/35% HD

FP = -4°F

37% GB/63% L

FP = -40°F

50% GB/50% CX

FP below -40°F

SECRET

SECRET

GB-4

6. CRLR 178 (1953)

50% GB/50% CX

FP below -195°C

7. CRLR 322 (1954)

50% GB/50% CX

FP below -65°C

B. Summary of Data and Selected Values

1. Physical state:

Pure GB is a colorless liquid of low volatility at room temperature.

2. Melting point:

-56°C (-69°F)

This is also the triple point - vapor pressure is 0.0015 mm Hg.

3. Normal boiling point:

152°C (305°F) (with decomposition)

4. GB of plant purity has the following characteristics:

Same appearance as the pure material.

MP below -56°C (-69°F)

C. Discussion

TCIR 513 (A3) and CRLR 2 (A4) contain the best work that has been done on the FP of GB to date. This compound apparently freezes so slowly and supercools to such a great extent that determining its FP from time-temperature curves, as was attempted in these two reports, becomes quite difficult. See the original reports for explanation. The values given in both reports therefore represent the highest temperatures to which the samples rose in the FP apparatus after supercooling; they are not considered to be the true FP's of the samples. The MP of -56.2°C given for sample #1 of TCIR 513 is thought to be a more accurate value than any of the FP's reported so far. A MP of -56°C therefore was selected for (B2). The true MP of GB probably lies within a degree of this value and slightly above it.

The vapor pressure at the TP (B2) was calculated from the following equation which was derived from the vapor pressure data of ETF 550Ca-1288 by the method of least squares (see category 13).

SECRET

SECRET

GB-4

$$\log p = 9.140 - \frac{2594}{T}$$

(range: -39° to 28°C
(273.2°K = 0.0°C))

This value was obtained by extrapolating the data over a temperature range of seventeen degrees. It is given to two significant figures, but probably is not quite that accurate.

The BP (B3) was obtained from the following vapor pressure equation which appears in Porton Technical Paper 278 (see category 13).

$$\log p = 8.5916 - \frac{2424.5}{T}$$

(range: 45° to 80°C)
(273.2°K = 0.0°C)

Since an extrapolation over a temperature range of more than seventy degrees was required in its calculation, the value is probably accurate within only a few degrees.

SECRET

SECRET

GB-5

CATEGORY 5

LIQUID DENSITY

A. Bibliography and Data

1. NDRC Inf. Rept. 9-4-1, NS 4 (1945)
OSRD 6400 (1945)
Redeman et al, J. Am. Chem. Soc. 70, 3604 (1948)

$$d = 1.0941 \text{ g/cm}^3 \text{ at } 25.6^\circ\text{C}$$

2. TDMR 1163 (1945)

$$\begin{aligned} d &= 1.1115 \text{ g/cm}^3 \text{ at } 10.05^\circ\text{C} \\ &1.0945 \text{ g/cm}^3 \text{ at } 25.2^\circ\text{C} \\ &1.0456 \text{ g/cm}^3 \text{ at } 68.4^\circ\text{C} \end{aligned}$$

3. Porton Technical Paper 278 (1952)

Pure GB

$$\begin{aligned} d: &\text{from } 1.1064 \text{ g/cm}^3 \text{ at } 10.0^\circ\text{C} \\ &\text{to } 1.0710 \text{ g/cm}^3 \text{ at } 40.0^\circ\text{C} \text{ (7 determinations)} \end{aligned}$$

The following equation was derived from these data:

$$d = 1.1182 - 0.00118t \quad (\text{range: } 10^\circ \text{ to } 40^\circ\text{C})$$

Pure GB

$$\begin{aligned} d: &\text{from } 1.1139 \text{ g/cm}^3 \text{ at } 10.0^\circ\text{C} \\ &\text{to } 1.0789 \text{ g/cm}^3 \text{ at } 40.0^\circ\text{C} \text{ (7 determinations)} \end{aligned}$$

The following equation was derived from these data:

$$d = 1.1255 - 0.001165t \quad (\text{range: } 10^\circ \text{ to } 40^\circ\text{C})$$

4. ETF 550Ca-1115 (1950)

Density data on the following mixtures are given:

GB/hexafluoroethane
GB/ethylene

SECRET

SECRET

GB-5

B. Selected Values

Liquid density

- (1) 1.16 g/cm³ at -40°C (-40°F)
- (2) 1.118 g/cm³ at 0°C (32°F)
- (3) 1.095 g/cm³ at 20°C (68°F)
- (4) 1.034 g/cm³ at 71°C (160°F)

GB of plant purity usually has a density of:

- (5) 1.12 to 1.13 g/cm³ at 0°C (32°F)
- (6) 1.09 to 1.10 g/cm³ at 20°C (68°F)

C. Discussion

Porton Technical Paper 278 (A3) contains the best data on the density of GB that have been reported to date. Values (B1) through (B4) were calculated from the following equation which was derived from these data by the authors.

$$d = 1.1182 - 0.00118t \quad (\text{range: } 10^{\circ} \text{ to } 40^{\circ}\text{C})$$

Although the data are given to five significant figures in the original report, they are probably not accurate to more than four. All values in paragraph B, excepting (B1), are given to four significant figures, therefore. Value (B1) was obtained by extrapolating the data over a temperature range of fifty degrees. An extrapolation of this magnitude was not considered possible without introducing appreciable error into the fourth significant figure of the value.

SECRET

SECRET

GB-6

CATEGORY 6

SOLUBILITY IN ORGANIC SOLVENTS

A. Bibliography and Data

1. ETF 550G-1260 (1944)

GB/AC
GB/MD

GB/chlorobenzene
GB/ethylene chloride

2. PR 2747 (1947)

GB is soluble in all common organic solvents.

3. ETF 550F-154 (Translation) (1949)

GB/ methyl alcohol

4. TCIR 513 (1949)

GB/toluene
GB/n-hexane
GB/p-cymene
GB/n-butyl benzene

GB/n-butyl chloride
GB/isopropyl benzene
GB/1, 1, 2-trichloroethane
GB/petroleum ether

5. ETF 550Ca-1150/1 June 1949 to 31 May 1950

GB/ethane
GB/ethylene
GB/hexafluoroethane

6. SO/R/816 (1952)

GB/ammonia

7. CRLR 178 (1953)
ETF 550-936 (1953)

GB/HD
GB/CX
GB/L

8. CRLR 322 (1954)

GB/CX

B. Summary of Data

GB is readily soluble in almost all common organic solvents.

SECRET

SECRET

GB-7

CATEGORY 7

SOLUBILITY IN WATER

A. Bibliography and Data

1. ETF 550E-6092 (1947)

GB was found to be almost completely miscible with water.

2. TCIR 369 (1947)

The solubility of GB in water was found to be greater than 52.3% by weight.

3. S.O./R./783 (1948)

GB is completely miscible with water.

4. 2d Ind, CMLRE-CR (CP), Proj 4-08-03-005, CmlC Cml and Rad Labs to CmlC Research and Engineering Command, 12 June 1952, subject: "Water solubility of G-agents," on letter, CMLEK-A, Chemical Corps Board, 29 Apr 1952.

GB is completely miscible with water.

B. Summary of Data

GB is completely miscible with water. This information was taken from the letter from CmlC Cml and Rad Labs to the CmlC Research and Engineering Command, CmlC (A4).

SECRET

SECRET

GB-8

CATEGORY 8

HYDROLYSIS

A. Bibliography and Data

1. Porton Tech. Paper 28 (1947)

k: from 1.92 per hour at pH 1.3 at 25°C
to 0.0171 per hour at pH 3.8 at 25°C (6 determinations)

2. TCIR 369 (1947)

At 25°C: from pH 1.8, $t_{1/2}$ = 7.5 hours
to pH 9.2, $t_{1/2}$ = 0.5 min. (6 determinations)

3. MDR 132 (1948)

At 25°C: from pH 6.0, $t_{1/2}$ = 47 hours
to pH 9.9, $t_{1/2}$ = 5 hours (4 determinations)

4. MDR 147 (1948)

5. Porton Tech. Paper 78 (1948)

k: from 1.92 per hour at pH 1.2 at 25°C
to 30.0 per hour at pH 10.7 at 25°C (7 determinations)

6. MDR 220 (1949)

At 22°C: from pH 7.3, $t_{1/2}$ = 18.7 hours
to pH 10.0, $t_{1/2}$ = 0.078 hours (9 determinations)

7. Porton Tech. Paper 150 (1950)

At 25°C: from pH 5.0, $t_{1/2}$ = 67 hours
to pH 8.9, $t_{1/2}$ = 0.23 hours (4 determinations)

$k = 4.37 \times 10^{-2}$ per min. at 15°C at pH 11.3
 10.2×10^{-2} per min. at 25°C at pH 11.3

8. Porton Tech. Paper 278 (1952)

9. ETF 100-29/Final (Task 9) Vol. 1, 2, 3, 6 (30 April 1954)

B. Selected Value

At 25°C (77°F) and pH 7.5, the half-life of hydrolysis of GB is 23 hours.

SECRET

SECRET

GB-8

C. Discussion

The above value was taken from the data of MDR 132 (A3). The rate of hydrolysis of GB is variable with pH and concentration. The half-life of hydrolysis of GB in an unbuffered solution was determined to be 30 hours (A2). GB hydrolyzes with the elimination of hydrofluoric acid.

SECRET

SECRET

GB-9

CATEGORY 9

EFFECTS OF HEAT AND BLAST

A. Bibliography

1. CRLR 3 (1951)
2. CRLR 13 (1951)
3. Porton Technical Paper 258 (1951)
4. Porton Technical Paper 265 (1952)
5. Kracke and DiPaola, CRLR report in preparation, Project 4-04-15-007, subject: Status Report, Dissemination of Toxic Agent by Thermal Generation (1954 or later).

B. Summary of Data

The thermal decomposition of GB consists of two simultaneous reactions: I) an autocatalytic and acid catalyzed decomposition into propene and methyl fluorophosphinic acid, and II) a disproportionation into methyl phosphonyl difluoride and di-isopropyl methyl phosphonate. Reaction I shows second order kinetics and reaction II first order kinetics. The velocity constants of the two reactions are as follows (A4):

Temperature °C	Reaction I k in hours ⁻¹	Reaction II k in hours ⁻¹
80	0.00370	0.000193
90	0.0118	0.000566
100	0.0236	0.00168
120	0.239	0.00765

The decomposition of GB is complete within about two and one-half hours at about 150°C (300°F) (A3).

GB decomposes roughly to the extent of about 10% when disseminated explosively (A1) and about 30% when disseminated by thermal generation (A5).

SECRET

SECRET

GB-10

CATEGORY 10

STABILITY IN STORAGE, ACTION ON METALS

A. Bibliography

1. PR 2762 (1952)
2. Porton Technical Paper 381 (1953)
3. Buckles and Crawford, CRLR report in preparation, subject: Corrosion by and Stabilization of GB (1954 or later).

B. Summary

GB of plant purity may be stabilized by the addition of one percent (by weight of GB) tri-n-butylamine in excess of the amount required to neutralize the apparent acidity. Thus stabilized it may be stored in steel for long periods of time at temperatures up to 71°C (160°F) with not more than 5 to 10% decomposition (most of which occurs during the first month or two) and no appreciable corrosion (A3).

Tri-n-butylamine and triethylamine appear to be about equally effective as stabilizers for GB. Tri-n-butylamine is used by the Americans while triethylamine is preferred by the British (A1, A2).

The decomposition of unstabilized GB is not appreciably greater than that of stabilized GB. Unstabilized GB develops undesirably high pressures within a few weeks after storage (A3).

SECRET

SECRET

GB-11

CATEGORY 11

LATENT HEAT OF VAPORIZATION

A. Bibliography and Data

1. TDMR 1163 (1945)

$$\Delta H_{\text{vap}} = 11.9 \text{ kcal/mol at } 30^{\circ} \text{ to } 57^{\circ}\text{C}$$

2. Porton Technical Paper 278 (1952)

$$\Delta H_{\text{vap}} = 11.1 \text{ kcal/mol at } 45^{\circ} \text{ to } 80^{\circ}\text{C}$$

B. Selected Values

Latent heat of vaporization:

(1) 11.9 kcal/mol (85.0 cal/g) at 20°C (68°F)

(2) 11.1 kcal/mol (79.3 cal/g) between 45° and 80°C (113° and 176°F)

C. Discussion

The values selected in paragraph B were calculated from the Clausius-Clapeyron equation and the vapor pressure data of ETF 550E-1288 (category 13, para A, item 13) and Porton Technical Paper 278 (A2). See category 13, para C, for a discussion of the vapor pressure data found in these two reports. Value (B1) was obtained from the following equation which was derived from the data of ETF 550E-1288:

$$\log p = 9.140 - \frac{2594}{T} \quad \begin{array}{l} \text{(range: } -39^{\circ} \text{ to } 28^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

Value (B2) was taken from the data of Porton Technical Paper 278. The H at the BP has not been calculated due to lack of data.

SECRET

SECRET

GB-12

CATEGORY 12

RELATIVE VAPOR DENSITY*

A. Bibliography

None

B. Selected Value

Relative vapor density: 4.84 (theoretical value)

*Relative vapor density = $\frac{\text{density of vapor at T and P}}{\text{density of air at T and P}}$

SECRET

SECRET

GB-13

CATEGORY 13

VAPOR PRESSURE

A. Bibliography and Data

1. CD Report 5/IS 73 (A. 2156) (1945)

$p = 8 \text{ mm Hg at } 59^{\circ}\text{C}$

2. NDRC Inf. Rept. 9-4-1, NS 4 (1945)

$p = 1.945 \text{ mm Hg at } 25^{\circ}\text{C}$

The next report of this series, NDRC Inf. Rept. 9-4-1, NS 5 (3), states that this value is not correct.

3. NDRC Inf. Rept. 9-4-1, NS 5 (1945)

Redeman et al, J. Am. Chem. Soc. 70, 3604 (1948)

$p = 2.18 \text{ mm Hg at } 25^{\circ}\text{C}$
 $6.26 \text{ mm Hg at } 40^{\circ}\text{C}$

These data were used to obtain the following equation:

$$\log p = 9.89902 - \frac{2850.9}{T} \quad (\text{range: } 25^{\circ} \text{ to } 40^{\circ}\text{C})$$

The following value obtained by distillation is also given:

$p = 15 \text{ mm Hg at } 56.5^{\circ} \text{ to } 57^{\circ}\text{C}$

This value also appears in TDMR 1163 (6).

4. OSRD 6391 (1945)

Distillation data were obtained on six different samples. Purest sample yielded:

$p = 13 \text{ mm Hg at } 47^{\circ}\text{C}$

5. OSRD 6400 (1945)

Two samples were distilled into two fractions each. Purest fraction yielded:

$p = 16 \text{ mm Hg at } 56.5^{\circ} \text{ to } 57^{\circ}\text{C}$

SECRET

SECRET

GB-13

6. TDMR 1163 (1945)

By transference method:

p: from 3.23 mm Hg at 30.0°C
to 10.79 mm Hg at 50.0°C (9 determinations)

By distillation (this value also appears in J. Am. Chem. Soc.
70, 3604 (3)):

p = 15 mm Hg at 56.5° to 57°C

The following equation was derived from the above data (including the distillation value) by the method of least squares:

$$\log p = 9.0887 - \frac{2606.6}{T} \quad (\text{range: } 30^{\circ} \text{ to } 50^{\circ}\text{C})$$

By static method:

p = 52.1 mm Hg at 79.8°C
54.4 mm Hg at 79.8°C

7. Porton Technical Paper 28 (1947)
Porton Technical Paper 62 (1948)
Porton Technical Paper 78 (1948)

p = 8 mm Hg at 46°C

This value also appears in Porton Technical Paper 29 (8).

8. Porton Technical Paper 29 (1947)

Sample #1 8mm Hg at 46°C
Sample #2 7 to 8 mm Hg at 38° to 40°C

9. SO/R/782 (1948)

Distillation data obtained on ten different samples:

p: from 10 mm Hg at 46°C
to 30 mm Hg at 69°C (10 determinations)

10. ETF 550F-154 (1949)

p = 8 mm Hg at 59°C

11. Porton Technical Paper 99 (1949)

p = 13.5 mm Hg at 51°C

SECRET

12. Porton Technical Paper 166 (1950)

Distillation data obtained on seven different samples:

p: from 9 mm Hg 46° to 46.5°C
to 12 mm Hg 50.2° to 50.8°C (7 determinations)

13. ETF 550Ca-1288 (1951)

p: from 0.011 mm Hg at -39.1°C
to 3.39 mm Hg at +28.3°C (8 determinations)

14. Porton Technical Paper 278 (1952)

Distillation data obtained on four different samples. Purest fraction yielded:

p = 1.5 mm Hg at 20°C

Distillate was used to obtain the following data (isoteniscope method):

p: from 9.4 mm Hg at 45.0°C
to 53.2 mm Hg at 80.0°C (8 determinations)

The authors derived the following equation from these data by the method of least squares:

$$\log p = 8.5916 - \frac{2424.5}{T} \quad \begin{array}{l} \text{(range: 45° to 80°C)} \\ \text{(273.2°K = 0.0°C)} \end{array}$$

The following data, obtained on a different sample by means of an effusion manometer, are also given:

p: from 0.74 mm Hg at 5.5°C
to 2.18 mm Hg at 19.5°C (5 determinations)

15. Porton Technical Paper 335 (1953)

Sample contained radioactive phosphorous (P₃₂).

p = 20 mm Hg at 80°C

The following reports contain vapor pressure data on various mixtures of GB with other compounds:

16. SO/R/783 (1948)

GB/isopropanol

SECRET

GB-13

17. SO/R/809 (1951)

GB/HCl

18. CRLR 178 (1953)

50% GB/50% CX $p = 2$ mm Hg at 25°C

19. CRLR 322 (1954)

50% GB/50% CX $p = 2$ to 3 mm Hg at 33° to 34°C
1 mol GB/1 mol CX $p = 7$ mm Hg at 59°C

B. Selected Values

Vapor pressure:

(1)	0.010	mm Hg at	-40°C	(-40°F)
(2)	0.096	mm Hg at	-18°C	(0°F)
(3)	0.44	mm Hg at	0°C	(32°F)
(4)	1.96	mm Hg at	20.0°C	(68.0°F)
(5)	13.4	mm Hg at	51.7°C	(125.0°F)
(6)	35.6	mm Hg at	71.1°C	(160.0°F)

C. Discussion

ETF 550Ca-1288 (A13) and Porton Technical Paper 278 (A14) contain what appear to be the most precise data on the vapor pressure of GB that have been reported so far. The data of these two reports are in excellent agreement.

The following equation was derived from the data of ETF 550Ca-1288 by the method of least squares:

$$\log p = 9.140 - \frac{2594}{T} \quad \begin{array}{l} \text{(range: } -39^{\circ} \text{ to } 28^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

This equation was used to calculate values (B1) through (B4). It does not appear anywhere else in the classified or unclassified chemical literature.

Values (B5) and (B6) were calculated from the following equation which was derived by the authors of Porton Technical Paper 278 from the data which they obtained by the isoteniscope method (A14):

$$\log p = 8.5916 - \frac{2424.5}{T} \quad \begin{array}{l} \text{(range: } 45^{\circ} \text{ to } 80^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

SECRET

SECRET

GB-14

CATEGORY 14

VOLATILITY IN ATMOSPHERIC AIR

A. Bibliography

None

B. Selected Values

Volatility in atmospheric air:

(1)	0.0096	$\times 10^4$	mg/m ³	at	-40	°C	(-40	°F)	(0.010	mm Hg)
(2)	0.084	$\times 10^4$	mg/m ³	at	-18	°C	(0	°F)	(0.096	mm Hg)
(3)	0.36	$\times 10^4$	mg/m ³	at	0	°C	(32	°F)	(0.44	mm Hg)
(4)	1.50	$\times 10^4$	mg/m ³	at	20.0	°C	(68.0	°F)	(1.96	mm Hg)
(5)	9.25	$\times 10^4$	mg/m ³	at	51.7	°C	(125.0	°F)	(13.4	mm Hg)
(6)	23.1	$\times 10^4$	mg/m ³	at	71.1	°C	(160.0	°F)	(35.5	mm Hg)

SECRET

SECRET

GB-16

CATEGORY 15

ODOR AND MEDIAN DETECTABLE CONCENTRATION

A. Bibliography

1. Porton Technical Paper 74 (1948)
2. Porton Memo 39 (1950)
3. MLSR 23 (1953)

B. Discussion

1. Odor cannot be definitely described but the sensation of detection is unmistakable (A3). Some observers claimed it to be "sweet or fruity" but none were able to recognize it again since the odor is so weak (A1).
2. Median detectable concentration by odor is 16 mg/m³ (A3).

SECRET

SECRET

GB-16

CATEGORY 16

TOXICITY BY INHALATION

A. Bibliography

MLSR 23 (1953)

B. Discussion

1. LC_{50} for a resting man: 100 mg. min/m³ (time: 2 to 10 minutes, based on body weight, intravenous injection, and agent retention in animal bodies).

LC_{50} for active man: 25 mg. min/m³ (time: 2 to 10 minutes, based on respiration rate being four times faster).

2. IC_{50} : 15 to 40 mg. min/m³ or for a defensive calculation, a value of 5 to 10 mg. min/m³ should be considered.
3. GB causes bronchoconstriction.
4. No data on the chronic toxicities of GB.

SECRET

SECRET

GB-17

CATEGORY 17

EYE TOXICITY

A. Bibliography

1. MDRR 18 (1950)
2. Porton Memo 39 (1950)
3. MSLR 23 (1953)

B. Discussion

It is estimated that 3.5 mg of liquid in the eye constitutes a lethal dose for man.

The eye effects produced by exposure to low dosages are manifestly due to local action of the vapor on the eye, since they occur to the same extent in men whose respiratory passages are protected by oronasal respirators as in unprotected men, and do not result if the observers wear close-fitting goggles, but are otherwise unprotected.

Threshold symptoms with vapor: 1.4 to 4.5 mg.min/m³ (time = 5 to 6 minutes).

Harassment exposure with vapor: 6.5 to 11.5 mg.min/m³ (time = 5 to 8 minutes for unprotected personnel).

No increase in severity of eye effects with vapor in range 14 to 45 mg.min/m³ for personnel protected only by oro-nasal respirators.

SECRET

SECRET

GB-18

CATEGORY 18

ORAL TOXICITY

A. Bibliography

1. MDRR 18 (1950)
2. MDRR 14 (1950)
3. MLSR 23 (1953)

B. Discussion

An LD₅₀ of 0.14 mg/kg (9.8 mg/70 kg man) carries cumulative effects which last for a period of days.

Water with more than 0.5 parts per million cannot be considered potable.

SECRET

SECRET

GB-19

CATEGORY 19

SKIN TOXICITY AND CLOTHING PENETRATION

A. Bibliography

1. MLSR 23 (1953)
2. Chemical Corps Board Study 13-52, Appendix B (1952)

B. Discussion

1. For vapor GB: Estimation of skin penetration under temperate conditions:

LC₅₀: 15,000 mg.min/m³
IC₅₀: 8,000 mg.min/m³

2. Liquid GB: Based on depilated animals:

LD₅₀: 1.5 gm/70 Kg man (20 mg/kg)
ID₅₀: not estimated.

3. Liquid GB does not injure the skin but penetrates rapidly and poisons the body.
4. Permeable clothing gives from two to three-fold protection regardless of the type of cloth, the number of layers and whether or not it was impregnated with CC2.

Generalization: Each layer of cloth doubles the LD₅₀ of liquid GB.

SECRET

SECRET

GB-20

CATEGORY 20

SPEED OF ACTION

A. Bibliography

1. MDR 201 (1949)
2. TCIR 616 (1950)

B. Discussion

1. Exposure to vapor:

Incapacitation within one hour after exposure to casualty doses (A1). Estimated time for incapacitation after exposure for unprotected troops, total exposure: 10 seconds to 5 minutes.

2. Liquid doses:

Estimated time for incapacitation by means of skin contamination is 20 minutes. It may be expected that lethal doses will kill within a few minutes.

SECRET

SECRET

GB-21

CATEGORY 21

DETOXICATION IN THE BODY

A. Bibliography

1. MDRR 18 (1950)
2. MLRR 114 (1953)
MDRR 229 (1953)

B. Discussion

Rate of detoxication in man is very low. A dose of 0.008 mg/Kg cannot be completely detoxified in 8 hours. A single dose of 0.008 mg/kg produces no observable effect. However, if this dose is repeated at 8 hour intervals, signs of poisoning appear after the fourth dose. The regression of symptoms indicates detoxication or compensatory adjustment by the body. The cumulative effect indicates that the rate of detoxication is less than 0.008 mg/kg/8 hours.

SECRET

SECRET

GB-22

CATEGORY 22

MEDICAL PROTECTIVE OR FIRST AID MEASURES

A. Bibliography

TM 8-285, Treatment of Chemical Warfare Casualties.

B. Discussion

In the treatment of GB casualties, speed of treatment is of the essence. Casualties should be removed from possibility of further contamination if possible and given an immediate injection of atropine and subjected to artificial resuscitation. Present thought is that atropine injection alone, while helpful in cases of mild exposure, is of little value in more severe exposure unless artificial resuscitation is applied. Either of these treatments alone is helpful but the combination of the two has more than the additive value. Thorough familiarization with the subject in reference TM 8-285 is strongly recommended.

SECRET

SECRET

GB-23

CATEGORY 23

DETECTION

A. Bibliography

1. Instructions - Kit, Chemical Agent Analyser, M10A1, Use of (27 April 1954).
2. Instructions - Kit, Chemical Agent Detector, M9A2.
3. Instructions - Kit, Water Testing, Poisons M-2 (14 July 1952).
4. TM 3-215, Military Chemistry and Chemical Agents.
5. TM 3-290, Individual Protective and Detection Equipment.
6. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Objectively, GB is detected by:

(1) Detector kit (M9A2). A greenish blue ring appears in white dot tube after wetting with solution from green top bottle. (Note: This is a general test and will be positive for G-agents and/or CK) (A2).

(2) Analyzer kit (M10A1). The standard test (A1) which contains granules from a white dot tube which are treated first with a solution of O-DN and then a solution of PER. An orange or amber color in the solution indicates the presence of G-agents (or CK).

(3) Water testing and screening (AN-M2). Nerve gases are detected by a color reaction and extraction of the color by an immiscible solvent (A6).

(4) Water testing kit, poisons (M4). This kit enables quantitative determination of G-agents (A3).

(5) Food testing and screening (ABC-M3). The nerve gases are identified by their reaction with two special chemicals to produce an orange or yellow color (A6).

(6) Vesicant detector crayon (M7, M7A1). Drops of liquid G-agent cause pink crayon markings or dust to turn yellow (A5).

(7) Liquid vesicant detector paint (M5). Surfaces painted with detector paint show a change in color from olive green to red when contaminated by drops or splashes of G-agents (A5).

SECRET

SECRET

GB-23

(8) Liquid vesicant detector paper (M6) (A5).

Subjectively, GB is detected by:

(1) Odor - none in pure state (A4).

(2) Physical appearance - colorless. liquid vaporizing to form colorless gas.

(3) Physiological symptoms - vapors may cause nausea, vomiting, and diarrhea followed by muscular twitching and convulsions. Even in low concentrations, vapor causes pupils to contract, and vision becomes difficult in dim light and headaches may result. A sense of tightness in the chest may be noticed. Contraction of the pupils may not appear as a warning sign of liquid penetration (A4, A6)

SECRET

SECRET

GB-24

CATEGORY 24

PROTECTION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents (August 1952).
2. TM 3-290, Individual Protective and Detection Equipment (September 1953).
3. TM 8-285, Treatment of Chemical Warfare Casualties (August 1951).

B. Summary

Protection against GB may be afforded by the use of the protective mask. Impermeable protective clothing is required for protection against liquid G-agents (A1, A3). Protective dubbing is also used (A2).

SECRET

SECRET

GB-25

CATEGORY 25

DECONTAMINATION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents.
2. TM 3-220, Decontamination
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

For personnel, soap and water rather than protective ointment are used for removing liquid contamination. Immediate and thorough action is necessary in removing nerve gases (A2). The following fluids are more satisfactory than soap and water and should be used if available:

- (1) A slurry of one part bleach in three parts of water.
- (2) A five to ten per cent solution of sodium carbonate.
- (3) A five to ten per cent solution of ammonium hydroxide.
- (4) A two per cent solution of sodium hydroxide.

If water alone is available, blot the excess liquid off the skin, then soak a fresh cloth with water and scrub the area turning the cloth with each bit of scrubbing to expose a clean surface. If a splash of liquid nerve gas should get into the eye, it should be flushed out immediately with water (A3).

For materiel and areas, in the case of liquid contamination, aeration, hot soapy water, bleach slurry, and solutions of commercially available alkalis, such as caustic soda and soda ash (A2). In confined areas, steam and ammonia are effective (A1).

SECRET

SECRET

GD-1

GD - SOMAN (German)

CATEGORY 1

SECONDARY SOURCES OF INFORMATION ON GD

Readers desiring information on GD which is beyond the scope of this document may find the following works of great value.

With Bibliography

CRLR 130 (revised) (1953)
ETF 100.25 (1948)
ETF 107-3 (1946)
ETF 550E-8327 (1951)
MDR 159 (1948)
MLSR 23 (1953)
Porton Memo 35 (1950)
TCIR 481 (1949)
TCR 36 (1949)

SECRET

SECRET

GD-2

CATEGORY 2

NAME, FORMULA, MOLECULAR WEIGHT

A. Bibliography

None

B. Summary

1. Technical name: 1,2,2 - Trimethylpropylmethyl phosphonofluoridate or Fluoromethylpinacolylphosphine oxide
2. Common name: Soman (German)
3. Chemical formula: $C_7H_{16}FO_2P$ or
$$\begin{array}{c} \text{F} \qquad \text{CH}_3 \text{ CH}_3 \\ | \qquad | \quad | \\ \text{CH}_3 - \text{P} - \text{O} - \text{CH} - \text{C} - \text{CH}_3 \\ || \qquad \qquad | \\ \text{O} \qquad \qquad \text{CH}_3 \end{array}$$
4. Molecular weight: 182.16

C. Discussion

This compound may also be found in the classified literature under the following code numbers:

EA 1210
T-2107 (British)

SECRET

SECRET

GD-3

CATEGORY 3

PHYSIOLOGICAL ACTION, TACTICAL USE, STATUS,
RUSSIAN INTEREST

A. Bibliography

None

B. Summary

1. Physiological action:

Nerve gas

2. Tactical use:

GD may be used as a non-persistent spray or persistent ground contaminant. It is very effective in producing immediate casualties.

3. Status:

None

4. Russian interest:

The Russians probably have some knowledge of this agent due to the fact that much information on German nerve gas research fell into their hands when Germany was invaded during World War II. Whether or not they have this agent in production is not known.

SECRET

SECRET

GD-4

CATEGORY 4

PHYSICAL STATE, MELTING POINT, BOILING POINT

A. Bibliography and Data

TDMR 1292 (1947)

FP is not readily determinable. Compound formed a glass but did not crystallize at the temperature of subliming carbon dioxide (-78°C).

BP = 167°C (calculated; category 13)

B. Summary of Data and Selected Values

1. Physical state:

Pure GD is a colorless liquid of low volatility at room temperature.

2. Melting point:

Not readily determinable.

3. Normal boiling point:

Compound begins to decompose rapidly at about 150°C (300°F). Theoretical BP: 160° to 170°C (320° to 340°F) (obtained by extrapolation of vapor pressure data).

SECRET

SECRET

GD-6

CATEGORY 5

LIQUID DENSITY

A. Bibliography and Data

TDMR 1292 (1947)

d_{400} 1.0363 g/cm³ at 10°C
1.0222 g/cm³ at 25°C
1.0130 g/cm³ at 35°C
0.9990 g/cm³ at 50°C

B. Selected Values

Liquid density:

- (1) 1.08 g/cm³ at -40°C (-40°F)
- (2) 1.046 g/cm³ at 0°C (32°F)
- (3) 1.027 g/cm³ at 20°C (68°F)
- (4) 0.980 g/cm³ at 71°C (160°F)

C. Discussion

TDMR 1292 contains the only density data available for this compound. These data were plotted on a density-temperature graph and values (B1) through (B4) were obtained therefrom by either interpolation or extrapolation. Although the data in the original report are given to five significant figures, they are not considered by the authors to be accurate to more than four. The values in paragraph B, excepting (B1) are given to four significant figures, therefore. Value (B1) was obtained by extrapolating the data over a temperature range of fifty degrees. An extrapolation of this magnitude was not considered possible without introducing appreciable error into the fourth significant figure of the value.

SECRET

SECRET

GD-6

CATEGORY 6

SOLUBILITY IN ORGANIC SOLVENTS

A. Bibliography

None

B. Summary

No data available. The solubility of GD in organic solvents is probably very similar to that of GB.

SECRET

SECRET

GD-7

CATEGORY 7

SOLUBILITY IN WATER

A. Bibliography and Data

Second Ind, CMLRE-CR (CP), proj 4-05-03-005, Cml C Cml and Rad
Labs to CmlC Research and Engineering Command, 12 June 1952,
subject: "Water Solubility of G-agents," on letter, CMLEK-A,
Chemical Corps Board, 29 April 1952.

Solubility = 3.4 g GD/100g solution at 0°C
2.1 g GD/100g solution at 20°C

B. Summary of Data

The solubility of GD in water is 21g GD/1000g solution at
20°C (68°F).

SECRET

SECRET

GD-8

CATEGORY 8

HYDROLYSIS

A. Bibliography and Data

1. TCIR 373 (1947)

At 25°C: from pH 2 , $t_{1/2} = 3$ hours
to pH 10 , $t_{1/2} = 60$ hours (5 determinations)

At 37°C: pH 7.4, $t_{1/2} = 1.75$ hours
pH 7.4, $t_{1/2} = 1.0$ hours

2. TCIR 393 (1947) TCIR 455 (1949)

at 25°C: pH 2, $k = 0.214$ per hour

3. Porton Tech. Paper 79 (1948)

k : from 2.81 per hour at pH 1.1 at 25°C
to 22.0 per hour at pH 10.7 at 25°C (8 determinations)

B. Selected Value

At 25°C (77°F) and pH 6.65, the half-life of hydrolysis of GD is 45 hours.

C. Discussion

The above value was taken from the data of TCIR 373 (A1). The rate of hydrolysis of GD is variable with pH. GD hydrolyzes with the elimination of hydrofluoric acid. The hydrolysis of 0.3 to 1.0% solutions of GD is substantially complete in twelve to fourteen hours, with half-hydrolysis being achieved in four to ten hours (A3). In 5% sodium hydroxide solution, hydrolysis was complete in less than five minutes (A1).

SECRET

SECRET

GD-9

CATEGORY 9

EFFECTS OF HEAT AND FLAST

A. Bibliography

ETP 650E-8327 (1951)

B. Summary

The thermal decomposition of GD is similar to that of GB. On heating to about 150°C (300°F) it pyrolyzes into methyl fluoro-phosphinic acid and isohexylene.

No data found on its stability to explosive dissemination.

SECRET

SECRET

GD-10

CATEGORY 10

STABILITY IN STORAGE, ACTION ON METALS

A. Bibliography

None

B. Summary

The stabilization of GD in storage could probably be accomplished by the same method that is used for GB.

SECRET

SECRET

GD-11

CATEGORY 11

LATENT HEAT OF VAPORIZATION

A. Bibliography and Data

1. TDMR 1292 (1947)

$$\Delta H_{\text{vap}} = 14.3 \text{ kcal/mol at } 25^{\circ} \text{ to } 50^{\circ}\text{C}$$

2. Porton Technical Paper 341 (1953)

$$\Delta H_{\text{vap}} = 14.2 \text{ kcal/mol at } 25^{\circ}\text{C}$$

B. Selected Value

Latent heat of vaporization at 20°C (68°F):

$$14.3 \text{ kcal/mol (78.6 cal/g)}$$

C. Discussion

The ΔH given in TDMR 1292 was selected in paragraph B because the vapor pressure data from which it was calculated were considered the best available (see category 13). Actually, the two values that have been reported (paragraph A) are in such good agreement that it makes little difference which is selected.

The selected value is given at 20°C for the sake of uniformity. The error introduced by assuming ΔH to be constant between 20° and 50°C is probably much less than the experimental error of the vapor pressure data.

SECRET

SECRET

GD-12

CATEGORY 12

RELATIVE VAPOR DENSITY*

A. Bibliography

None

B. Selected Value

Relative vapor density: 6.30 (theoretical value)

*Relative vapor density = $\frac{\text{density of vapor at T and P}}{\text{density of air at T and P}}$

SECRET

SECRET

GD-13

CATEGORY 13

VAPOR PRESSURE

A. Bibliography and Data

1. TDMR 1292 (1947)

By transference method -

p: from 0.293 mm Hg at 25°C
to 1.96 mm Hg at 50°C (13 determinations)

The authors derived the following equation from the above data by the method of least squares:

$$\log p = 9.9877 - \frac{3129}{T} \quad \begin{array}{l} \text{(range: 25° to 50°C)} \\ \text{(273.2°K = 0.0°C)} \end{array}$$

The following value was obtained by vacuum distillation is also given in the report:

p = 23 mm Hg at 92°C

2. TDMR 1314 (1947)

p = 10 mm Hg at 75° to 78°C

3. Porton Technical Paper 29 (1947)

Sample #1 p = 5 mm Hg at 66°C

Sample #2 p = 8 to 9 mm Hg at 74°C

4. Porton Technical Paper 99 (1949)
Porton Technical Paper 166 (1950)

p = 11 mm Hg at 79°C

5. Porton Technical Paper 335 (1953)

Sample contained radioactive phosphorous (P₃₂)

p = 5 mm Hg at 80°C

SECRET

SECRET

GD-13

6. Porton Technical Paper 341 (1953)

By effusion manometer -

p: from 0.33 mm Hg at 20°C
to 1.16 mm Hg at 36°C (5 determinations)

The following equation was derived from these data by the method of least squares:

$$\log p = 10.108 - \frac{3101}{T} \quad \begin{array}{l} \text{(range: } 20^{\circ} \text{ to } 36^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

B. Selected Values

Vapor pressure:

- (1) 0.034 mm Hg at 0°C (32°F)
- (2) 0.20 mm Hg at 20°C (68°F)
- (3) 2.2 mm Hg at 52°C (125°F)
- (4) 7.9 mm Hg at 71°C (160°F)

C. Discussion

TDMR 1292 (A1) and Porton Technical Paper 341 (A6) contain the only precise vapor pressure data that have been reported on GD to date. The data of both reports were plotted on a log p vs. 1/T graph. Although the two sets of data have almost identical slopes (see category 11), their positions on the graph were found to be considerably different. The distillation data that are available were plotted in an effort to verify the data of one or the other report. All of the distillation data (including those reported by the British) corroborated the data of TDMR 1292. An extrapolation of the Porton data failed to pass through any of the distillation points. The values given in paragraph B therefore were taken from the TDMR report. They were calculated from the following equation which was derived from the TDMR data by the method of least squares (A1).

$$\log p = 9.9877 - \frac{3129}{T} \quad \begin{array}{l} \text{(range: } 25^{\circ} \text{ to } 50^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

Values (B1) through (B4) were all obtained by extrapolation of the data; (B1) and (B4) are probably the least accurate of the four due to the larger extrapolations involved in their calculation.

No values were obtained at temperatures below 0°C because of the lack of data.

SECRET

SECRET

GD-14

CATEGORY 14

VOLATILITY IN ATMOSPHERIC AIR

A. Bibliography

None

B. Selected Values

Volatility in atmospheric air:

(1)	0.36	$\times 10^3$	mg/m ³	at	0°C (32°F)	(0.034	mm Hg)
(2)	2.0	$\times 10^3$	mg/m ³	at	20°C (68°F)	(0.20	mm Hg)
(3)	20.	$\times 10^3$	mg/m ³	at	52°C (125°F)	(2.2	mm Hg)
(4)	65.	$\times 10^3$	mg/m ³	at	71°C (160°F)	(7.9	mm Hg)

SECRET

SECRET

GD-15

CATEGORY 15

ODOR AND MEDIAN DETECTABLE CONCENTRATION

A. Bibliography

1. ETF 550E-6047 (1947)
2. Porton Technical Paper 74 (1948)
3. MDRR 8 (1950)

B. Discussion

1. The odor is described as being sweet or fruity or musty.
2. Median detectable concentration is $7 \pm 2.4 \text{ mg/m}^3$ (A3).

SECRET

SECRET

GD-16

CATEGORY 16

TOXICITY BY INHALATION

A. Bibliography

Porton Memo 34 (1949)

B. Discussion

1. LCt_{50} for GD is about 10% more toxic than GB.

LCt_{50} for GD is 180 to 270 mg/m^3 (time is 10 minutes) based on animal data.

2. No data found for the median incapacitating dose for GD.
3. GD causes bronchoconstriction.
4. No data found on the chronic toxicities of GD.

SECRET

SECRET

GD-17

CATEGORY 17

LYE TOXICITY

No data found.

SECRET

SECRET

GD-18

CATEGORY 18

ORAL TOXICITY

No data found.

SECRET

SECRET

GD-19

CATEGORY 18

SKIN TOXICITY AND CLOTHING PENETRATION

A. Bibliography

1. ETF 550G-1736 (1949)
2. ETF 550-611/7 (1952)

B. Discussion

One drop on the skin, especially on the face, of liquid GD must be regarded as fatal (A1).

No effects in man were observed with the application of 30 mg. liquid GD to the skin (A2).

SECRET

SECRET

GD-20

CATEGORY 20

SPEED OF ACTION

No data found.

SECRET

SECRET

GD-21

CATEGORY 21

DETOXICATION IN THE BODY

No data found.

SECRET

SECRET

GD-22

CATEGORY 22

MEDICAL PROTECTIVE OR FIRST AID MEASURES

A. Bibliography

TM 8-285, Treatment of Chemical Warfare Casualties

B. Discussion

In the treatment of GD casualties, speed of treatment is of the essence. Casualties should be removed from possibility of further contamination if possible and given an immediate injection of atropine and subjected to artificial resuscitation. Present thought is that atropine injection alone, while helpful in cases of mild exposure, is of little value in more severe exposure unless artificial resuscitation is applied. Either of these treatments alone is helpful but the combination of the two has more than the additive value. Thorough familiarization with the subject in reference TM 8-285 is strongly recommended.

SECRET

SECRET

GD-23

CATEGORY 23

DETECTION

A. Bibliography

1. Instructions - Kit, Chemical Agent Analyzer, M10A1, Use of (27 April 1954).
2. Instructions - Kit, Chemical Agent Detector, M9A2.
3. Instructions - Kit, Water Testing, Poisons M-2 (14 July 1952).
4. TM 3-290, Individual Protective and Detection Equipment.
5. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Objectively, GD is detected by:

- (1) Detector kit (M9A2). A greenish-blue ring appears in white dot tube after wetting with solution from green top bottle. (Note: This is a general test and will be positive for G-agents and/or CK) (A2).
- (2) Analyzer kit (M10A1). The standard test (A1) which contains granules from a white dot tube which are treated first with a solution of O-DN and then a solution of PER. An orange or amber color in the solution indicates the presence of G-agents (or CK).
- (3) Water testing and screening (AN-M2). Nerve gases are detected by a color reaction and extraction of the color by an immiscible solvent (A5).
- (4) Water testing kit, poisons (M4). This kit enables quantitative determination of G-agents (A3).
- (5) Food testing and screening (ABC-M3). The nerve gases are identified by their reaction with two special chemicals to produce an orange or yellow color (A5).
- (6) Vesicant detector crayon (M7, M7A1). Drops of liquid G-agents cause pink crayon markings or dust to turn yellow (A4).
- (7) Liquid vesicant detector paint (M5). Surfaces painted with detector paint show a change in color from olive green to red when contaminated by drops or splashes of G-agents (A4).

SECRET

SECRET

GD-23

(8) Liquid vesicant detector paper (M8) (A4).

Subjectively, GD is detected by:

(1) Odor - GD has a fruity odor; with impurities, it has an odor of camphor.

(2) Physical appearance - colorless liquid vaporizing to form colorless gas.

(3) Physiological symptoms - vapors may cause nausea, vomiting, and diarrhea followed by muscular twitching and convulsions. Even in low concentrations, vapor causes pupils to contract, and vision becomes difficult in dim light and headaches may result. A sense of tightness in the chest may be noticed. Contraction of the pupils may not appear as a warning sign of liquid penetration (A4, A5).

SECRET

SECRET

GD-24

CATEGORY 24

PROTECTION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents.
2. TM 3-290, Individual Protective and Detection Equipment.
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Protection against GD may be afforded by use of the protective mask. Impermeable protective clothing is required for protection against liquid G-agent (A1, A3). Protective dubbing is also used (A2).

SECRET

SECRET

GD-25

CATEGORY 25

DECONTAMINATION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents.
2. TM 3-220, Decontamination
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

For personnel, soap and water rather than protective ointment are used for removing liquid contamination. Immediate and thorough action is necessary in removing nerve gases (A2). The following fluids are more satisfactory than soap and water and should be used if available:

- (1) A slurry of one part bleach in three parts of water.
- (2) A five to ten per cent solution of sodium carbonate.
- (3) A five to ten per cent solution of ammonium hydroxide.
- (4) A two per cent solution of sodium hydroxide.

If water alone is available, blot the excess liquid off the skin, then soak a fresh cloth with water and scrub the area turning the cloth with each bit of scrubbing to expose a clean surface. If a splash of liquid nerve gas should get into the eye, it should be flushed out immediately with water (A3).

For materiel and areas, in the case of liquid contamination, aeration, hot soapy water, bleach slurry, and solutions of commercially available alkalis, such as caustic soda and soda ash (A2). In confined areas, steam and ammonia are effective (A1).

SECRET

SECRET

GF-1

CATEGORY 1

SECONDARY SOURCES OF INFORMATION ON GF

Readers desiring information on GF which is beyond the scope of this document may find the following works of great value.

With Bibliography

CRLR 164 (revised) (1954)
ETF 100.25 (1948)
ETF 107-3 (1946)
ETF 550E-8327 (1951)
MDR 159 (1948)
MLSR 23 (1953)
Porton Memo. 35 (1950)
TCIR 481 (1949)
TCR 36 (1949)

SECRET

GF-2

<u>NAME</u>	<u>FORMULA</u>	<u>MOLECULAR WEIGHT</u>
1. Ethanol	C ₂ H ₆ O	46.07
2. Methanol	CH ₄ O	32.04
3. Propan-2-ol	C ₃ H ₈ O	60.10
4. Butan-2-ol	C ₄ H ₁₀ O	74.12
5. Pentan-3-ol	C ₅ H ₁₂ O	88.15
6. Hexan-4-ol	C ₆ H ₁₄ O	102.17
7. Heptan-5-ol	C ₇ H ₁₆ O	116.20
8. Octan-6-ol	C ₈ H ₁₈ O	130.23
9. Nonan-7-ol	C ₉ H ₂₀ O	144.26
10. Decan-8-ol	C ₁₀ H ₂₂ O	158.28

None

1. Technical name:	Cyclohexyl methylphosphonofluoridate or Cyclohexyloxyfluoromethylphosphine Oxide
2. Common name:	Cyclohexyl methylphosphonofluoridate

3. Chemical formula: $C_7H_{14}FO_2P$ or $CH_3 - \begin{array}{c} F \\ | \\ P \\ | \\ O \end{array} - O - \begin{array}{c} CH \\ | \\ CH_2 - CH_2 \end{array} \begin{array}{c} CH_2 - CH_2 \\ \diagdown \quad / \\ CH_2 \end{array}$

4. Molecular weight: 180.14

C. Discussion

This compound may also be found in the classified literature under the following code numbers:

CA 1212
T-2139 (British)

SECRET

SECRET

GF-3

CATEGORY 3

PHYSIOLOGICAL ACTION, TACTICAL USE, STATUS
RUSSIAN INTEREST

A. Bibliography

1. ETF 550R-1120 (1952)
2. CRLR 199 (1953)

B. Summary

1. Physiological action:

Nerve gas

2. Tactical use:

GF may be used as a non-persistent spray or persistent ground contaminant. It is very effective in producing immediate casualties.

3. Status:

None

4. Russian interest:

Whether the Russians are interested specifically in this agent is not known. There is good reason to believe that they are engaged in nerve gas research at the present time, however, and probably have some knowledge of this and many other similar compounds.

SECRET

SECRET

GF-4

CATEGORY 4

PHYSICAL STATE, MELTING POINT, BOILING POINT

A. Bibliography and Data

1. TDMR 1292 (1947)

FP between -30°C and -50°C

2. Chief, Chemical Division, CmIC Chemical and Radiological Laboratories, Bi-Weekly Report, Period Ending 21 March 1952, Project 4-08-03-005.

FP below -30°C (metastable form)

MP = -12°C

B. Summary of Data and Selected Values

1. Physical state:

Pure GF is a colorless liquid of low volatility at room temperature.

2. Melting point:

-12°C (10°F)

Freezing point is below -30°C (-22°F). When GF is cooled below this temperature, a metastable, crystalline form freezes out which, upon long standing, slowly converts into a stable form melting at -12°C . So far, the stable form has never been obtained directly upon cooling (A2).

3. Normal boiling point:

Compound begins to decompose rapidly at about 150°C (300°F). Theoretical BP: about 200°C (390°F) (obtained by extrapolation of vapor pressure data).

SECRET

SECRET

GP-5

CATEGORY 5

LIQUID DENSITY

A. Bibliography and Data

1. TDMR 1292 (1947)

$d = 1.1426 \text{ g/cm}^3 \text{ at } 10^\circ\text{C}$
 $1.1276 \text{ g/cm}^3 \text{ at } 25^\circ\text{C}$
 $1.1179 \text{ g/cm}^3 \text{ at } 35^\circ\text{C}$
 $1.1031 \text{ g/cm}^3 \text{ at } 50^\circ\text{C}$

2. Chief, Chemical Division, CmlC Chemical and Radiological Laboratories, BI-Weekly Report, Period Ending 21 March 1952, Project 4-08-03-005.

$d = 1.125 \text{ g/cm}^3 \text{ at } 25^\circ\text{C}$
 $1.116 \text{ g/cm}^3 \text{ at } 35^\circ\text{C}$
 $1.101 \text{ g/cm}^3 \text{ at } 50^\circ\text{C}$

3. ETF 550Ca-1115 (1950)

Data on the density of various GF/ethane mixtures may be found in this report.

B. Selected Values

Liquid density:

- (1) $1.19 \text{ g/cm}^3 \text{ at } -40^\circ\text{C} (-40^\circ\text{F})$
- (2) $1.153 \text{ g/cm}^3 \text{ at } 0^\circ\text{C} (32^\circ\text{F})$
- (3) $1.133 \text{ g/cm}^3 \text{ at } 20^\circ\text{C} (68^\circ\text{F})$
- (4) $1.082 \text{ g/cm}^3 \text{ at } 71^\circ\text{C} (160^\circ\text{F})$

C. Discussion

TDMR 1292 appears to contain the best data available on the density of GF. These data were plotted on a density-temperature graph and values (B1) through (B4) were obtained either by interpolation or extrapolation. Although the data are given in the original report to five significant figures, they are not considered by the authors to be accurate to more than four. The values in paragraph B, excepting (B1), are given to four significant figures, therefore. Value (B1) was obtained by extrapolating the data over a temperature range of fifty degrees. An extrapolation of this magnitude was not considered possible without introducing appreciable error into the fourth significant figure of the value.

SECRET

SECRET

GF-6

CATEGORY 6

SOLUBILITY IN ORGANIC SOLVENTS

A. **Bibliography and Data**

ETF 550Ca-1115 (1950)

ETF 550Ca-1150/1 June 1949 to 31 May 1950

GF/ethane

B. **Summary of Data**

The solubility of GF in organic solvents is probably very similar to that of GB.

SECRET

SECRET

GF-7

CATEGORY 7

SOLUBILITY IN WATER

A. Bibliography and Data

Second Ind, CMLRE-CR (CP), Proj 4-08-03-005, CmlC Cml and Rad
Labs to CmlC Research and Engineering Command, 12 June 1952,
subject: "Water solubility of G-agents," on letter, CMLEK-A,
Chemical Corps Board, 29 April 1952.

Solubility = 5.1g GF/100g of solution at 0°C
3.7g GF/100g of solution at 20°C

B. Summary of Data

The solubility of GF in water is 37g GF/1000g solution at
20°C (68°F).

SECRET

SECRET

GP-8

CATEGORY 8

HYDOLYSIS

A. Bibliography and Data

TCIR 393 (1947)

TCIR 455 (1949)

At 25°C: $k = 0.232$ per hour at pH 2
 $t_{1/2} = 42$ hours (no pH specified)

B. Selected Value

At 25°C (77°F), the half-life of hydrolysis of GP is 42 hours
(no pH specified).

C. Discussion

The rate of hydrolysis of GP is variable with pH. GP hydrolyses
with the elimination of hydrofluoric acid.

SECRET

SECRET

GF-9

CATEGORY 9

EFFECTS OF HEAT AND BLAST

A. Bibliography

Porton Technical Paper 258 (1951)

B. Summary

The thermal decomposition of GF is similar to that of GB. On heating to about 150°C (300°F) GF pyrolyzes to methyl fluorophosphinic acid, cyclohexane, methyl phosphonyl difluoride, and other products. Decomposition is complete within about two hours.

No data found on its stability to explosive dissemination.

SECRET

UNCLASSIFIED

GF-10

CATEGORY 10

STABILITY IN STORAGE. ACTION ON METALS

A. Bibliography

None

B. Summary

The stabilization of GF in storage could probably be accomplished by the same method that is used for GB.

UNCLASSIFIED

4.09

SECRET

GF-11

CATEGORY 11

LATENT HEAT OF VAPORIZATION

A. Bibliography and Data

Porton Technical Paper 341 (1953)

$$\Delta H_{\text{vap}} = -15.3 \text{ kcal/mol at } 25^{\circ}\text{C}$$

B. Selected Value

Latent heat of vaporization at 20°C (68°F):

15.3 kcal/mol (85.0 cal/g)

C. Discussion

The value in paragraph B is given at 20°C for the sake of uniformity. It actually represents the average ΔH of GF between 15° and 31°C (see category 13, para A, item 6).

SECRET

UNCLASSIFIED

GF-12

CATEGORY 12

RELATIVE VAPOR DENSITY*

A. Bibliography

None

B. Selected Value

Relative vapor density: 6.23 (theoretical value)

*Relative vapor density = $\frac{\text{density of vapor at T and P}}{\text{density of air at T and P}}$

UNCLASSIFIED

SECRET

GF-13

CATEGORY 13

VAPOR PRESSURE

A. Bibliography and Data

1. TDMR 1292 (1947)

Transference method used. Compound proved to be so unstable in the apparatus that the experiment had to be discontinued after the following data were obtained.

$p = 0.056$ mm Hg at 25°C
 0.064 mm Hg at 25°C
 0.040 mm Hg at 25°C

The following value obtained by vacuum distillation is also given:

$p = 2.5$ mm Hg at 63° to 64°C

2. TDMR 1314 (1947)

$p = 3$ mm Hg at 82°C

3. Porton Technical Paper 99 (1949)

$p = 1.5$ mm Hg at 71°C

4. SO/R/803 (1951)

$p = 4$ mm Hg at 85°C

5. Porton Technical Paper 335 (1953)

Sample contained radioactive phosphorous (P_{32}).

$p = 1$ mm Hg at 80°C

6. Porton Technical Paper 341 (1953)

By effusion manometer -

p : from 0.026 mm Hg at 15°C
to 0.105 mm Hg at 31°C (6 determinations)

SECRET

SECRET

GF-13

The following equation was derived from the above data by the method of least squares:

$$\log p = 10.062 - \frac{3347}{T} \quad \begin{array}{l} \text{(range: } 15^{\circ} \text{ to } 31^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

D. Selected Values

Vapor pressure:

- (1) 0.0063 mm Hg at 0°C (32°F)
- (2) 0.044 mm Hg at 20°C (68°F)
- (3) 0.56 mm Hg at 52°C (125°F)
- (4) 2.2 mm Hg at 71°C (160°F)

C. Discussion

Porton Technical Paper 341 (A6) contain the only precise vapor pressure data on GF that are available. Values (B1) through (B4) were calculated from the following equation which was derived from the data of this report by the method of least squares (A6).

$$\log p = 10.062 - \frac{3347}{T} \quad \begin{array}{l} \text{(range: } 15^{\circ} \text{ to } 31^{\circ}\text{C)} \\ \text{(273.2}^{\circ}\text{K} = 0.0^{\circ}\text{C)} \end{array}$$

All of the values selected, excepting (4), were obtained by extrapolation of the data. Value (B4) is probably the least accurate of the four due to the large extrapolation (forty degrees) involved in its calculation.

Values were not obtained at temperatures below 0°C because of the lack of data.

SECRET

UNCLASSIFIED

GF-14

CATEGORY 14

VOLATILITY IN ATMOSPHERIC AIR

A. Bibliography

None

B. Selected Values

Volatility in atmospheric air:

(1)	0.067	$\times 10^3$	mg/m ³	at	0°C (32°F)	(0.0063 mm Hg)
(2)	0.43	$\times 10^3$	mg/m ³	at	20°C (68°F)	(0.044 mm Hg)
(3)	5.0	$\times 10^3$	mg/m ³	at	52°C (125°F)	(0.56 mm Hg)
(4)	18	$\times 10^3$	mg/m ³	at	71°C (160°F)	(2.2 mm Hg)

UNCLASSIFIED

SECRET

GF-15

CATEGORY 15

ODOR AND MEDIAN DETECTABLE CONCENTRATION

A. Bibliography

ETF 550-611/7 (1952)

B. Discussion

1. No data on the odor of GF.
2. The median detectable concentration is similar to that of GB (16 mg/m³).

SECRET

UNCLASSIFIED

GP-16

CATEGORY 16

TOXICITY BY INHALATION

No data available.

UNCLASSIFIED

4.15

UNCLASSIFIED

GF-17

CATEGORY 17

EYE TOXICITY

No data available

UNCLASSIFIED

UNCLASSIFIED

GF-18

CATEGORY 18

ORAL TOXICITY

No data available.

UNCLASSIFIED

SECRET

GF-10

CATEGORY 19

SKIN TOXICITY AND CLOTHING PENETRATION

A. Bibliography

1. Chemical Corps Board Study 13-52 (1952)
2. MLRR 119 (1953)

B. Discussion

1. For vapor GF:

$$\begin{aligned} \text{LCt}_{50} &= 15,000 \text{ mg. min/m}^3 \\ \text{ICt}_{50} &= 8,000 \text{ mg. min/m}^3 \end{aligned}$$

2. For liquid GF:

$$\begin{aligned} \text{LD}_{50} &= 0.14 \text{ gm/70 Kg man (naked)} \\ \text{LD}_{50} &= 0.84 \text{ gm/70 Kg man (single layer HBT)} \\ &\text{No data on ID}_{50} \text{ for liquid GF.} \end{aligned}$$

3. GF does not affect the skin but when it is absorbed, it poisons the system.
4. Based on pig data, an LD_{50} would require an air-spray ground contamination of 8 g/m^2 for masked troops by skin absorption. Protection afforded by a single-layer HBT cloth covering on pigs was six-fold against liquid GF.

SECRET

UNCLASSIFIED

GF-20

CATEGORY 20

SPEED OF ACTION

No data found.

UNCLASSIFIED

UNCLASSIFIED

GF-21

CATEGORY 2:

DETOXICATION IN THE BODY

No data found.

UNCLASSIFIED

UNCLASSIFIED

GF-22

CATEGORY 22

MEDICAL PROTECTIVE OR FIRST AID MEASURES

A. Bibliography

TM 8-285, Treatment of Chemical Warfare Casualties

B. Discussion

In the treatment of GF casualties, speed of treatment is of the essence. Casualties should be removed from possibility of further contamination if possible and given an immediate injection of atropine and subjected to artificial resuscitation. Present thought is that atropine injection alone, while helpful in cases of mild exposure, is of little value in more severe exposure unless artificial resuscitation is applied. Either of these treatments alone is helpful but the combination of the two has more than the additive value. Thorough familiarization with the subject in reference TM 8-285 is strongly recommended.

UNCLASSIFIED

UNCLASSIFIED

GF-23

CATEGORY 23

DETECTION

A. Bibliography

1. Instructions - Kit, Chemical Agent Analyzer, M10A1, Use of (27 April 1954).
2. Instructions - Kit, Chemical Agent Detector, M9A2.
3. Instructions - Kit, Water Testing, Poisons M-2 (14 July 1952).
4. TM 3-290, Individual Protective and Detection Equipment.
5. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Objectively, GF is detected by:

- (1) Detector kit (M9A2). A greenish-blue ring appears in white dot tube after wetting with solution from green top bottle. (Note: This is a general test and will be positive for G-agents and/or CK) (A2).
- (2) Analyzer kit (M10A1). The standard test (A1) which contains granules from a white dot tube which are treated first with a solution of O-DN and then a solution of PER. An orange or amber color in the solution indicates the presence of G-agents (or CK).
- (3) Water testing and screening (AN-M2). Nerve gases are detected by a color reaction and extraction of the color by an immiscible solvent (A5).
- (4) Water testing kit, poisons (M4). This kit enables quantitative determination of G-agents (A3).
- (5) Food testing and screening (ABC-M3). The nerve gases are identified by their reaction with two special chemicals to produce an orange or yellow color (A5).
- (6) Vesicant detector crayon (M7, M7A1). Drops of liquid G-agent cause pink crayon markings or dust to turn yellow (A4).
- (7) Liquid vesicant detector paint (M5). Surfaces painted with detector paint show a change in color from olive green to red when contaminated by drops or splashes of G-agents (A4).

UNCLASSIFIED

UNCLASSIFIED

GF-23

(8) Liquid vesicant detector paper (M6) (A4).

Subjectively, GF is detected by:

(1) Physical appearance - colorless liquid vaporizing to form colorless gas.

(2) Physiological symptoms - vapors may cause nausea, vomiting, and diarrhea followed by muscular twitching and convulsions. Even in low concentrations, vapor causes pupils to contract, and vision becomes difficult in dim light and headache may result. A sense of tightness in the chest may be noticed. Contraction of the pupils may not appear as a warning sign of liquid penetration (A4, A5).

UNCLASSIFIED

UNCLASSIFIED

GP-24

CATEGORY 24

PROTECTION

A. Bibliography

1. TM 3-215, Military Chemistry and Chemical Agents.
2. TM 3-290, Individual Protective and Detection Equipment.
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

Protection against GP may be afforded by the use of the protective mask. Impermeable protective clothing is required for protection against liquid G-agents (A1, A3). Protective dubbing is also used (A2).

UNCLASSIFIED

UNCLASSIFIED

GF-26

CATEGORY 25

DECONTAMINATION

A. Bibliography

1. TM 3-216, Military Chemistry and Chemical Agents.
2. TM 3-220, Decontamination.
3. TM 8-285, Treatment of Chemical Warfare Casualties.

B. Summary

For personnel, soap and water rather than protective ointment are used for removal of liquid contamination. Immediate and thorough action is necessary in removing nerve gases (A2). The following fluids are more satisfactory than soap and water and should be used if available:

- (1) A slurry of one part bleach in three parts of water.
- (2) A five to ten per cent solution of sodium carbonate.
- (3) A five to ten per cent solution of ammonium hydroxide.
- (4) A two per cent solution of sodium hydroxide.

If water alone is available, blot the excess liquid off the skin, then soak a fresh cloth with water and scrub the area turning the cloth with each bit of scrubbing to expose a clean surface. If a splash of liquid nerve gas should get into the eye, it should be flushed out immediately with water (A3).

For materiel and areas, in the case of liquid contamination, aeration, hot soapy water, bleach slurry, and solutions of commercially available alkalis, such as caustic soda and sea ash (A2).

UNCLASSIFIED

SECRET

NERVE GASES

1	2	3	4	5	6	7	
Symbol	Technical Name, Common Name, Formula and Molecular Weight	Physiological Action, Tactical Use, Status, Russian Interest	Physical State at Room Temperature, Melting Point, Boiling Point	Liquid Density in g/cm ³	Solubility in Organic Solvents	Solubility in Water	
GA	Ethyl dimethylphosphoramide-cyanidate Cyanodimethylaminoethoxy-phosphine oxide Tabun $\begin{array}{c} \text{CH}_3 \\ \\ \text{N} - \text{P} - \text{O} - \text{C}_2\text{H}_5 \\ \quad \\ \text{CH}_3 \quad \text{CN} \\ \\ \text{O} \end{array}$ 162.13	Nerve gas Usually employed as a nonpersistent spray or persistent ground contaminant. It is very effective in producing immediate casualties. Limited Standard Russians have great interest in GA as a warfare agent.	Colorless liquid of low volatility FP = -38°F BP = 430° to 465°F GA of plant purity: Amber to brown in color FP = -38°F	1.139 at -40°F 1.100 at 32°F 1.080 at 68°F 1.031 at 160°F GA of plant purity: 1.09 to 1.11 at 32°F 1.07 to 1.09 at 68°F	Readily soluble in almost all common organic solvents.	72g GA/1000g. solution at 68°F.	At he of re en st bu
GB	Isopropyl methylphosphonofluoridate Fluoroisopropoxymethyl-phosphine oxide Sarin $\begin{array}{c} \text{F} \quad \text{CH}_3 \\ \quad \\ \text{CH}_3 - \text{P} - \text{O} - \text{CH} \\ \quad \\ \text{O} \quad \text{CH}_3 \end{array}$ 140.11	Nerve gas Usually disseminated as a non-persistent spray. It is very effective in producing immediate casualties. Standard Russians have great interest in GB as a warfare agent.	Colorless liquid of low volatility MP = -69°F BP = 305°F (with decomposition) GB of plant purity: Same appearance as the pure compound. MP = below -69°F	1.16 at 40°F 1.118 at 32°F 1.095 at 68°F 1.034 at 160°F GB of plant purity: 1.12 to 1.13 at 32°F 1.09 to 1.10 at 68°F	Readily soluble in almost all common organic solvents.	GB is completely miscible with water.	At he of re is co ly ti so
GD	1,2,2-Trimethylpropylmethyl phosphonofluoridate Fluoromethylpinacolyloxy-phosphine oxide Soman $\begin{array}{c} \text{F} \quad \text{CH}_3 \quad \text{CH}_3 \\ \quad \quad \\ \text{CH}_3 - \text{P} - \text{OCH} - \text{C} - \text{CH}_3 \\ \quad \quad \\ \text{O} \quad \quad \text{CH}_3 \end{array}$ 182.16	Nerve gas Usually employed as a nonpersistent spray for persistent ground contaminant. It is very effective in producing immediate casualties. None Russians probably have knowledge of this agent. Whether or not they have this agent in production is not known.	Colorless liquid of low volatility FP not readily determinable BP = 220° to 240° (theoretical)	1.08 at -40°F 1.046 at 32°F 1.027 at 68°F 0.980 at 160°F	The solubility of GD in organic solvents is probably very similar to that of GB.	21g GD/1000g. solution at 68°F.	At he of re va dr ne se dr dr le
GF	Cyclohexyl methylphosphonofluoridate Cyclohexyloxyfluoromethyl-phosphine oxide. Cyclohexyl methyl phosphonofluoridate $\begin{array}{c} \text{F} \quad \text{CH}_2 - \text{CH}_2 \\ \quad \\ \text{CH}_3 - \text{P} - \text{O} - \text{CH} \\ \quad \\ \text{O} \quad \text{CH}_2 - \text{CH}_2 \end{array}$ 180.14	Nerve gas Usually employed as a nonpersistent spray or persistent ground contaminant. It is very effective in producing immediate casualties. None Whether the Russians are interested specifically in this agent is not known.	Colorless liquid of low volatility. FP = 10°F BP = 390°F	1.19 at -40°F 1.153 at 32°F 1.133 at 68°F 1.082 at 160°F	The solubility of GF in organic solvents is probably very similar to that of GB.	37g GF/1000g. solution at 68°F.	At he he of GF el f

NERVE GASES

2

6	7	8	9	10	11	12
<p>Solubility in Organic Solvents</p> <p>GA is readily soluble in most all common organic solvents.</p>	<p>Solubility in Water</p> <p>72g GA/1000g. solution at 68°F.</p>	<p>Rate of Hydrolysis</p> <p>At 68°F and pH 7.0, the half-life of hydrolysis of GA is 8.5 hours. GA reacts slowly with water and fairly rapidly with strong alkalis with self-buffering at pH 4.5.</p>	<p>Effects of Heat and Blast</p> <p>GA is inflammable in air. Its closed-up flash point in atmospheric air (760 mm Hg) is 172°.</p> <p>Decomposition takes place within three hours at 300°F.</p> <p>GA undergoes considerable decomposition when disseminated explosively or disseminated by thermal generation.</p>	<p>Stability in Storage, Action on Metals</p> <p>GA is stable in steel for several years but has been found to undergo complete decomposition within three months at 150°F.</p> <p>The corrosion rate of GA on steel has been found to be 3.4×10^{-5} inches penetration per month at 150°F.</p>	<p>Latent Heat of Vaporization</p> <p>16 kcal/mol (100 cal/g) at 68°F.</p>	<p>Relative Vapor Density</p> <p>5.60 (theoretical value)</p>
<p>Solubility in Organic Solvents</p> <p>GB is readily soluble in most all common organic solvents.</p>	<p>GB is completely miscible with water.</p>	<p>At 77°F and pH 7.5 the half-life of hydrolysis of GB is 23 hours. The rate of hydrolysis of GB is variable with pH and concentration. GB hydrolyzes with the elimination of hydrofluoric acid.</p>	<p>Decomposition of GB is complete within two and one-half hours at about 300°F.</p> <p>GB decomposes roughly to the extent of about 10% when disseminated explosively and about 30% when disseminated by thermal generation.</p>	<p>Tri-n-butyl and triethylamine appear to be about equally effective as stabilizers for GB. Thus stabilized it may be stored in steel for long periods of time at temperatures up to 160°F with not more than 5 to 10% decomposition and no appreciable corrosion.</p> <p>The decomposition of unstabilized GB is not appreciably greater than that of stabilized GB.</p>	<p>11.9 kcal/mol (85.0 cal/g) at 68°F.</p> <p>11.1 kcal/mol (79.3 cal/g) between 113° and 176°F.</p>	<p>4.84 (theoretical value)</p>
<p>The solubility of GD in organic solvents is probably very similar to that of GB.</p>	<p>21g GD/1000g. solution at 68°F.</p>	<p>At 77°F and pH 6.65, the half-life of hydrolysis of GD is 45 hours. The rate of hydrolysis is variable with pH. GD hydrolyzes with the elimination of hydrofluoric acid. In 5% sodium hydroxide solution, hydrolysis was complete in less than five minutes.</p>	<p>On heating GD to about 300°F, it pyrolyzes into methyl fluorophosphinic acid and isohexylene.</p> <p>No data found on its stability to explosive dissemination.</p>	<p>The stabilization of GD in storage could probably be accomplished by the same method that is used for GB.</p>	<p>14.3 kcal/mol (85.6 cal/g) at 68°F.</p>	<p>6.30 (theoretical value)</p>
<p>The solubility of GF in organic solvents is probably very similar to that of GB.</p>	<p>37g GF/1000g. solution at 68°F.</p>	<p>At 77°F, the half-life of hydrolysis of GF is 42 hours (no pH specified). GF hydrolyzes with the elimination of hydrofluoric acid.</p>	<p>Decomposition takes place within two hours at 300°F. GF pyrolyzes to methyl fluorophosphinic acid, cyclohexene, methyl phosphonyl difluoride and other products.</p> <p>No data found on its stability to explosive dissemination.</p>	<p>The stabilization of GF in storage could probably be accomplished by the same method that is used for GB.</p>	<p>15.3 kcal/mol (85.0 cal/g) at 68°F.</p>	<p>6.23 (theoretical value)</p>

SECRET

NERVE GASES (Cont'd)

13	14	15	16	17	18	19
Vapor Pressure	Volatility in Atmospheric Air in mg/m ³	Odor and Median Detectable Concentration	Toxicity by Inhalation	Eye Toxicity	Oral Toxicity	Skin Toxicity and Clothing Penetration
0.006 mm Hg at 32°F 0.037 mm Hg at 68°F 0.4 mm Hg at 125°F 2 mm Hg at 160°F	0.06x10 ³ at 32°F (0.006 mm Hg) 0.33x10 ³ at 68°F (0.037 mm Hg) 3 x10 ³ at 125°F (0.4 mm Hg) 15 x10 ³ at 160°F (2 mm Hg)	Fruity or sweet odor. Median detectable concentration is 2.2 mg/m ³ by odor.	Median lethal exposure is 500 mg min/m ³ for 10 min exposure. Median incapacitating exposure is 100 mg min/m ³ for a 10 minute exposure. G-agents cause strangulation by bronchial constriction.	Agent is toxic to eyes. Vapor causes pupil of eye to contract.	No human data	Body exposure (vapor): Incapacitation at 12,000 mg min/m ³ ; median lethal exposure is 20,000 mg min/m ³ . Skin contamination (liquid): Median lethal dosage is 0.23 gm/70 kg man (estimated from animal data). One drop on skin will cause death of man in a short time.
0.010 mm Hg at -40°F 0.096 mm Hg at 0°F 0.44 mm Hg at 32°F 1.96 mm Hg at 68°F 13.4 mm Hg at 125°F 35.5 mm Hg at 160°F	0.0096x10 ⁴ at -40°F (0.010 mm Hg) 0.084 x10 ⁴ at 0°F (0.096 mm Hg) 0.36 x10 ⁴ at 32°F (0.44 mm Hg) 1.50 x10 ⁴ at 68°F (1.96 mm Hg) 9.25 x10 ⁴ at 125°F (13.4 mm Hg) 23.1 x10 ⁴ at 160°F (35.5 mm Hg)	Scarcely detectable by odor. Median detectable concentration is 16 mg/m ³ by odor.	Lethal exposure: 100 mg min/m ³ for a resting man (2 to 10 minutes). Incapacitation: 15 to 40 mg min/m ³ . Inhalation causes strangulation due to bronchial constriction.	3.5 mg/70 kg man of liquid in eye constitutes a lethal dose for men. Vapor in low concentrations causes the pupil of the eye to contract.	Median lethal dosage of 9.8 mg/70kg man carries cumulative effects which last for days.	Vapor: Incapacitation at 8,000 mg min/m ³ in temperate conditions; lethal exposure equals 15,000 mg min/m ³ in temperate conditions. Liquid: In temperate conditions, lethal exposure equals 1.5 gm/70 kg man. Liquid dose does not injure skin but penetrates rapidly and poisons the body.
0.034 mm Hg at 32°F 0.20 mm Hg at 68°F 2.2 mm Hg at 125°F 7.9 mm Hg at 160°F	0.36x10 ³ at 32°F (0.034 mm Hg) 2.0 x10 ³ at 68°F (0.20 mm Hg) 20 x10 ³ at 125°F (2.2 mm Hg) 65 x10 ³ at 160°F (7.9 mm Hg)	Sweet, fruity, or musty odor. Median detectable concentration is 7 mg/m ³ .	Median lethal exposure for GD is about 10% more toxic than GB. Inhalation causes strangulation due to bronchial constriction.	No data found. Probably the same as GB.	No human data.	Agent is highly toxic by skin absorption. Liquid does not injure the skin but poisons the body.
0.0063 mm Hg at 32°F 0.044 mm Hg at 68°F 0.56 mm Hg at 125°F 2.2 mm Hg at 160°F	0.067x10 ³ at 32°F (0.0063 mm Hg) 0.43 x10 ³ at 68°F (0.044 mm Hg) 5.0 x10 ³ at 125°F (0.56 mm Hg) 18 x10 ³ at 160°F (2.2 mm Hg)	No data on odor of GF. Median detectable concentration is similar to that of GB.	No data found.	No data found.	No human data.	Vapor: Same as for GB. Liquid: Lethal dosage equals 0.14 gm/70 kg man (naked), 0.84 gm/70 kg man (single layer EBT).

SECRET

SECRET

18	19	20	21	22	23	24	25
Specificity	Skin Toxicity and Clothing Penetration	Speed of Action	Detoxication in the Body	Medical Protective or First Aid Measures	Detection	Protection	Decontamination
data	Body exposure (vapor): Incapacitation at 12,000 mg min/m ³ ; median lethal exposure is 20,000 mg min/m ³ . Skin contamination (liquid): Median lethal dose is 0.83 gm/70 kg men (estimated from animal data). One drop on skin will cause death of man in a short time.	Very rapid, death usually within 1 hour after exposure.	No human data.	Termination of exposure, atropine administration, resuscitation, and use of anti-convulsive drugs.	MGA2 detector kit; MLOA1 analyzer kit; chloramine-T with a solution of gamma-picoline and phenylpyresolone. By constriction of chest, then by miosis. Solution of dinitro-dine and peroxide yields an orange or amber color.	Leakproof gas mask and impermeable protective clothing.	For personnel use hot soapy water. For contaminated areas, use bleach slurry and dilute alkali solutions. In confined areas, steam and ammonia are effective.
data) 9.8 men cumulative data for	Vapor: Incapacitation at 3,000 mg min/m ³ in temperate conditions; lethal exposure equals 15,000 mg min/m ³ in temperate conditions. Liquid: In temperate conditions, lethal exposure equals 1.5 gm/70 kg men. Liquid dose does not injure skin but penetrates rapidly and poisons the body.	Very rapid, death usually within 20 minutes after exposure.	Detoxication in man is very low. It is cumulative.	Termination of exposure, atropine administration, resuscitation, and use of anti-convulsive drugs.	MGA2 detector kit; MLOA1 analyzer kit; solution of dinitro-dine and peroxide yields an orange or amber color. By constriction of chest, then by miosis.	Leakproof gas mask and impermeable protective clothing.	For personnel, use hot soapy water. For contaminated areas, use bleach slurry and dilute alkali solutions. In confined areas, steam and ammonia are effective.
data.	Agent is highly toxic by skin absorption. Liquid does not injure the skin but poisons the body.	No data found.	No data found.	Termination of exposure, atropine administration, resuscitation, and use of anti-convulsive drug.	MGA2 detector kit; MLOA1 analyzer kit; solution of dinitro-dine and peroxide yields an orange or amber color. By constriction of chest, then by miosis.	Leakproof gas mask and impermeable protective clothing.	For personnel, use hot soapy water. For contaminated areas, use bleach slurry and dilute alkali solutions. In confined areas, steam and ammonia are effective.
data.	Vapor: Same as for GB. Liquid: Lethal dosage equals 0.14 gm/70 kg men (naked), 0.84 gm/70 kg men (single layer MHT).	No data found.	No data found.	Termination of exposure, atropine administration, resuscitation and use of anti-convulsive drugs.	MGA2 detector kit; MLOA1 analyzer kit; solution of dinitro-dine and peroxide yields an orange or amber color. By constriction of chest, then by miosis.	Leakproof gas mask and impermeable protective clothing.	For personnel, use hot soapy water. For contaminated areas, use bleach slurry and dilute alkali solutions. In confined areas, steam and ammonia are effective.



DEPARTMENT OF THE ARMY
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
EDGEWOOD CHEMICAL BIOLOGICAL CENTER
5183 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MD 21010-5424

REPLY TO
ATTENTION OF

RDCB-DPC-RS

FEB 18 2016

MEMORANDUM THRU Director, Edgewood Chemical Biological Center, (RDCB-D/Dr. Joseph L. Corriveau), 5183 Blackhawk Road, Aberdeen Proving Ground, Maryland 21010-5424

FOR Defense Technical Information Center (DTIC), 8725 John J. Kingman Road, Ft Belvoir, VA 22060-6218

SUBJECT: Request for Change in Distribution

1. This action is in response to an Edgewood Chemical Biological Center (ECBC) internal request for a Change in Distribution for the attached listed documents.
2. The listed documents have current distribution statements or classifications which limit their release. ECBC Subject Matter Experts have reviewed the documents and deem them all suitable for the change in distribution to read "Distribution A: Approved for public release; distribution unlimited."
3. The point of contact is Adana Eilo, ECBC Security Specialist, (410) 436-2063 or adana.l.eilo.civ@mail.mil.

Encl


RONALD L. STAFFORD
Security Manager

1. *Report on Properties of War Gases*, Volume 1, G-Agents (U), Chemical Corps Board, Army Chemical Center, MD, **1956**, CONFIDENTIAL Report, (AD-108 456).
2. Rueggeberg, W. H. C.; Ginsburg, A. *The Synthesis of MCE, Cyano (Dimethylamino) Ethoxyphosphine Oxide*, Chemical Warfare Service Technical Data Memorandum Report 1138, **1945** (ADB968799) Dist. "D"
3. Doyle, W. L., et al. *Informal Monthly Progress Report on Toxicity and Irritancy of Chemical Agents*, No. N.S. 3, The University of Chicago Toxicity Laboratory in cooperation with The Medical Division, Chemical Warfare Service, U.S. Army and the Bureau of Medicine and Surgery, U.S. Navy, **1945**. (CBRNIAC-CB-068173) Dist. "E"
4. Panariello, V. Monthly Intelligence Report, 40th Chemical Laboratory Company, April **1945**. (HDIAC-2075468) Dist. "E"
5. Snyder, Jr., H. L.; Hudgin, D. E.; Schlesinger, A. *Captured Material Technical Report #60, New German Chemical Warfare Agent, A Cyano Phosphate*, 44th Chemical Laboratory Company, APO 298, US Army, **1945**. (HDIAC-2075719) Dist. "E"
6. Reuggeberg, W.H.C. *German Agent MCE, Letter Report of Visit to University of Chicago and University of Illinois*, Chemical Division, Edgewood Arsenal, MD, **1945**. (CBRNIAC-CB-114805) Dist. "E"
7. Samuel, J. B.; Penski, E. C.; Callahan, J. J. *Physical Properties of Standard Agents, Candidate Agents, and Related Compounds at Several Temperatures*, UNCLASSIFIED Special Publication ARCSL-SP-83015, U.S. Army Chemical Systems Laboratory, Aberdeen Proving Ground, MD, **1983**, (ADC033491) Dist. "E"
8. Abercrombie, P.L. *Physical Property Data Review of Selected Chemical Agents and Related Compounds: Updating Field Manual 3-9 (FM 3-9)*; ECBC TR-294; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, **2003**; Report (ADB294480) Dist. "D"
9. Chemical Agent Data Sheets, Volume 1, EO-SR-74001, Department of the Army, Headquarters, Edgewood Arsenal, Aberdeen Proving Ground, Maryland, **1974**. (CBRNIAC-CB-007206) Dist. C (export controlled)
10. War Department Memorandum, Subject: New German Gas, MCE, Preliminary Report, 19 June **1945**. (CBRNIAC-CB-093876)

Encl